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M.Sc. in Civil Engineering

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**REPUBLIC OF TURKEY
GAZIANTEP UNIVERSITY
GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES**

**ASSESSMENT OF GROUNDWATER QUALITY IN THE
GAZA STRIP BY USING GIS**

**M.Sc. THESIS
IN
CIVIL ENGINEERING**

**BY
ABDULMUNEM TELFAH
AUGUST 2022**

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M.Sc. Thesis

in

**Civil Engineering
Gaziantep University**

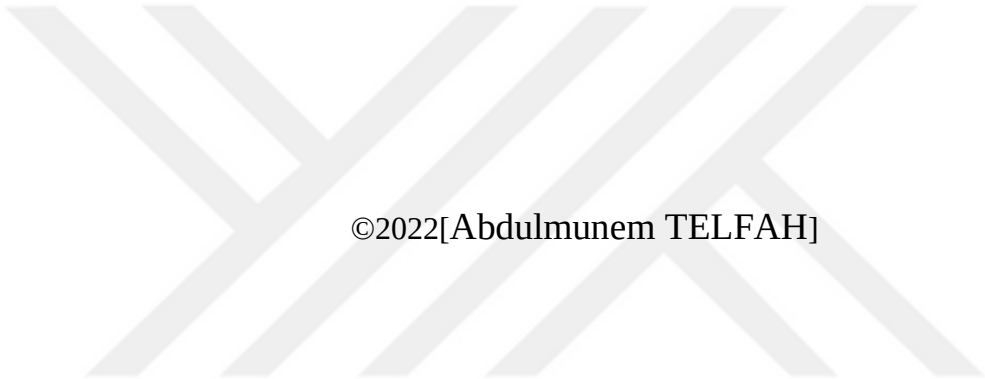
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by

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August 2022



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Abdulmunem Khaled TELFAH

ABSTRACT

ASSESSMENT OF GROUNDWATER QUALITY IN THE GAZA STRIP BY USING GIS

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M.Sc. in Civil Engineering
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The study aimed to use GIS systems to create and publish digital maps to assess the quality of groundwater in the Gaza Strip from 2007 to 2015. It also explained the ability of GIS to study water and its characteristics and assess the general status of groundwater. A strong relationship was found between the increase in population and the steady increase in the volume of pollution and between water pollution with chemicals (nitrates - sodium -chloride - potassium - magnesium - water hardness - dissolved solids - calcium) and diseases (liver - kidneys - nervous system). The study also showed a significant increase in the level of pollution of the chemical properties of drinking water, especially (nitrates - chlorides - dissolved solids), which reached more than five times what was determined by the World Health Organization standards for water. Ten different wells were selected to study the impact of the current situation scenario on the concentration of chemical elements in the future. This scenario indicates that there is a relationship between the water level and the concentration of chemical elements in the aquifer, and therefore the concentration rates in the southern regions of the Gaza Strip are higher than in the northern regions. The concentrations of chemical elements were predicted during the next 35 years depending on the population growth rate in the strip and the concentrations of chemical elements from 2016 to 2021 using the MT3DMS code with stress periods from 2025 to 2055. The transit model was run for this scenario as the current situation, and thus the result was an increased significant levels of groundwater pollution with the chemical elements.

Key Words: Groundwater, GIS, GMS MODFLOW, Chemical pollution, Gaza Map.

ÖZET

GAZZE ŞERİDİNDE YERALTI SUYU KALİTESİNİN CBS İLE DEĞERLENDİRİLMESİ

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M.Sc. in Civil Engineering

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118 Sayfa

Çalışma, 2007'den 2015'e kadar Gazze Şeridi'ndeki yeraltı suyunun kalitesini değerlendirmek için dijital haritalar oluşturmak ve yayınlamak için CBS sistemlerini kullanmayı amaçladı. Çalışma, Gazze Şeridi'ndeki yeraltı suyunun tükenmeye ve kirliliğe maruz kaldığını ve yıldan yıla. Ayrıca CBS'nin suyu ve özelliklerini inceleme ve yeraltı suyunun genel durumunu değerlendirme yeteneğini de açıkladı. Nüfus artışı ile kirlilik hacmindeki sürekli artış arasında ve kimyasallarla su kirliliği (nitratlar - sodyum -klorür - potasyum - magnezyum - su sertliği - çözünmüş katılar - kalsiyum) ve hastalıklar (karaciğer - böbrekler) arasında güçlü bir ilişki bulundu. - gergin sistem). Çalışma ayrıca, içme suyunun kimyasal özelliklerinin, özellikle (nitratlar - klorürler - çözünmüş katılar) kirlilik seviyesinde, Dünya Sağlık Örgütü'nün su standartlarının belirlediğinin beş katından fazlasına ulaşan önemli bir artış gösterdi. Mevcut durum senaryosunun gelecekteki kimyasal elementlerin konsantrasyonu üzerindeki etkisini incelemek için on farklı kuyu seçildi. Bu senaryo, akiferdeki su seviyesi ile kimyasal elementlerin konsantrasyonu arasında bir ilişki olduğunu ve bu nedenle Gazze Şeridi'nin güney bölgelerindeki konsantrasyon oranlarının kuzey bölgelerinden daha yüksek olduğunu göstermektedir. 2025 ile 2055 arasındaki stres dönemleri ile MT3DMS kodu kullanılarak şeritteki nüfus artış hızına ve 2016 ile 2021 arasındaki kimyasal element konsantrasyonlarına bağlı olarak önümüzdeki 35 yıl boyunca kimyasal element konsantrasyonları tahmin edilmiştir. Bunun için geçiş modeli çalıştırılmıştır. Mevcut durum olarak senaryo ve dolayısıyla sonuç, kimyasal elementlerle yeraltı suyu kirliliğinin önemli düzeyde artmasıydı.

Anahtar Kelimeler: Yeraltı suyu, GIS, GMS MODFLOW, Kimyasal kirlilik, Gazze Haritası.



"Dedicated to my family"

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“GOD Thank you for giving me the strength and encouragement especially during all the challenging moments in completing this thesis. I am truly grateful for your exceptional love and grace during this entire journey”.

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I would like to dedicate this dissertation to my beloved parents, my father and my mother. They sacrificed their lives to raise me to be a better person. I hope I have made you both proud.

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LIST OF ABBREVIATIONS

WHO	World Health Organization
GIS	Geographic Information System
TDS	Total Dissolved Solids
CL	Chloride
Na	Sodium
NO₃	Nitrate
Mg	Magnesium
Ca	Calcium
K	Potassium
Hardness	Hardness

CHAPTER 1

INTRODUCTION

1.1 Introduction

The water problem is one of the most prominent problems that have increased in severity in recent times, especially in Arab countries, and the reason for this is the difference in the water balance between the limited water resources available and the increasing demand for it, and the geographical and geological location of the Arab world has contributed to limited water, as it is located within the arid and semi-arid region, Which is considered one of the regions with limited water resources, The Gaza Strip is one of the areas that fall within this climate, which is characterized by With the limited water resources as well as the instability of climatic conditions and rainfall and the loss of most of the rain water, in addition to the population density that the Gaza Strip suffers from, as well as other problems to which water is exposed, such as the increase in the percentage of pollution, and the excessive and uncontrolled withdrawal of water from wells, and incorrect utilization with available sources such as household, agricultural and industrial uses.

The study was applied to the Gaza Strip using geographic information systems (GIS), where the Gaza Strip is one of the areas that suffer from an imbalance in the water balance because it is located in a dry and semi-arid climate, which suffers from limited water resources, in addition to the Gaza Strip is considered one of the most densely populated areas and one of the most developed areas in the world Population growth rates, where the population of the Gaza Strip has reached about 19 million people (Herzallah and Mukhtar ,2016), they live on an area of no more than 365 km².

The importance of GIS applications in the use of the land is due to the fact that it is an effective and modern way to deal with the huge amount of data; It is characterized by a high ability to analyze data, which helps planners to reach correct decisions that

may be difficult to reach by traditional methods; This is due to the feature of integrating information through linking or collecting a group from different data in different layers that can be dealt with automatically, and benefited from it without prejudice to its accuracy, validity or significance Therefore, systems technology was used geographical information systems (GIS) in the study through spatial analysis in the evaluation and identification of water wells and the preparation of a database on the local environment of the sector. The importance of using GIS is that it is a tool to create and publish water pollution maps and put them on the Internet, as this technology is designed to be a tool that enables users and researchers to create, edit, modify, upload, publish, manipulate, and analyze spatial and linear geographic data, and users can access it online without the need to possess knowledge and experience.

1.2 Problem Statement

The phenomenon of water pollution in the Gaza Strip is growing and increasing gradually due to many factors, the most important of which are population growth and economic deterioration due to the Israel blockade. The water has about 100 million cubic meters annually, which led to the phenomenon of sea water creeping into the depth of the aquifer, and a deterioration in the chemical and biological properties of the water.

1.3 Study Area

The Gaza Strip is located on the eastern coast of the Mediterranean Sea, located between latitudes 31 degrees and 13 minutes and 14 seconds and 31 degrees and 35 minutes and 45 seconds in the north and longitudes 34 degrees and 13 minutes and 3 seconds and 34 degrees and 34 minutes and 5 seconds in the east (Abu Samra ,2014), bordered on the south by the Sinai desert, with a border of 16 km, and on the east and north Palestine occupied in 1948 reaches to 45 km, and the length of the coast on the Mediterranean is about 40 km, and its width varies between 6-12 km, and the total area of the sector is 365 km (Abu Samra ,2014), and the Gaza Strip is formed from five governorates represented in the North Gaza Governorate, the Gaza Governorate, and the Central Governorate, Khan Yuns Governorate, Rafah Governorate, and the topography of the governorates descends from east to west to re aches maximum is 100 m above sea level in some eastern regions. Figure 1.1 shows the geographical map of the Gaza.

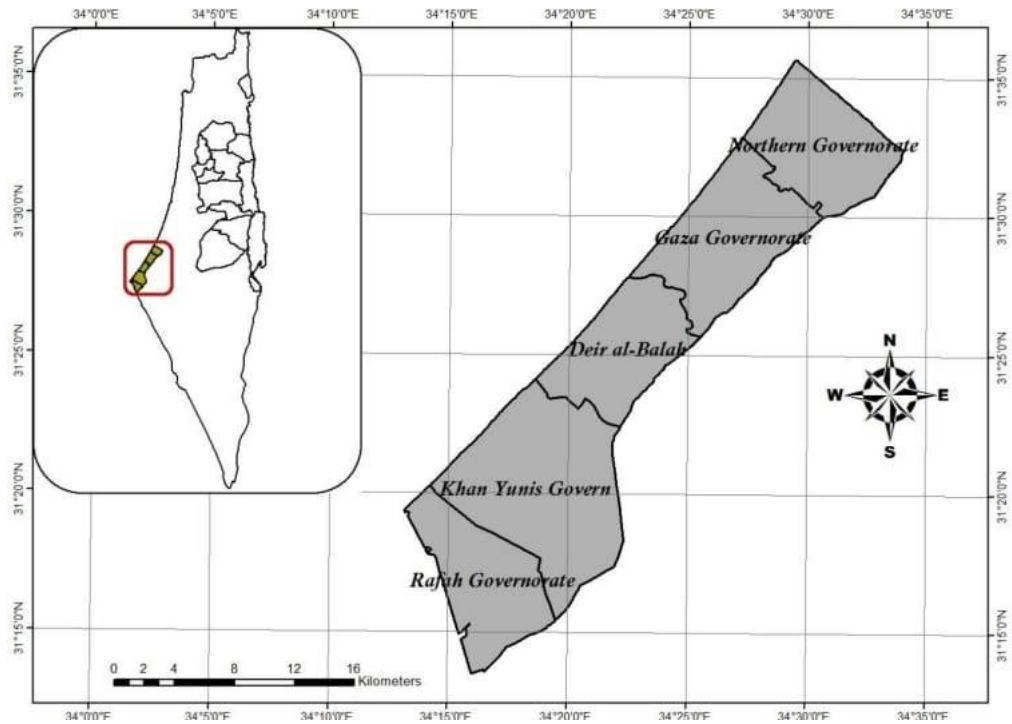


Figure 1.1 The geographical map of the Gaza

1.4 The Importance of Studying

- a) Public opinion participation in the extent of water pollution in the governorates of Gaza.
- b) Create a website that includes all information related to researchers and those interested in the field of Groundwater pollution in the Gaza Strip, and this site will be accessible to all.
- c) Illuminating water from groundwater "drinking water" Gaza, to come up with conclusions, recommendations and suggestions to alleviate the medical problems there and handle it properly.

1.5 Objectives of the Study.

- a) Using GIS to create and upload digital maps for assessment the quality of groundwater wells "municipal wells" in the Gaza Strip and community participation and awareness of the extent of pollution.
- b) Preparing a digital map of the water wells in the study area using (GIS) technology.
- c) Public participation in the amount of pollution generated.
- d) Preparing a spatial database for the chemical properties of drinking water in the Gaza Strip.

- e) Knowing the quality of the water in the aquifer, its suitability for human uses, and its compliance with the standards of the World Health Organization.
- f) Identify the most important diseases that the population has contracted as a result of drinking water.

1.6 Study Time Limit

The study covers the time period from 2007-2015, and the time limit of the study was related to the extent of the study availability of data covering the study area, which the researcher was able to obtain, to assess the situation the present and the possibility of predicting the future.

1.7 population in Gaza Strip.

The population of the Gaza Strip is about 2 million, with a growth rate of approximately 3.8% (PCBS, 2007), spread over five main governorates. Gaza City Governorate, is the largest governorate in terms of population, with a population of about 695,967 people. The southern governorates formed by Khan Yuns and Rafah are the other main governorates. The population of Khan Yuns Governorate is about 401,582 people, while the population of Rafah Governorate is about 252,703 (Palestinian Central Bureau of Statistics, 2020). Table 1.1 shows the population estimate in the Gaza Strip as presented by the Palestinian Central Bureau of Statistics in 2020.

Table 1.1 The estimated population in Gaza Strip (PCBS, 2007).

Year	Population	Growth Rate (%)	Year	Population	Growth Rate (%)
2001	1,188,130	4	2011	1,732,438	3.5
2002	1,236,372	4	2012	1,792,895	3.4
2003	1,286,109	3.9	2013	1,854,353	3.3
2004	1,337,236	3.9	2014	1,917,019	3.3
2005	1,389,789	3.8	2015	1,980,825	3.2
2006	1,443,814	3.8	2016	1,828,614	3.2
2007	1,499,369	3.8	2017	1,876,666	2.6
2008	1,556,201	3.7	2018	1,932,843	2.9
2009	1,614,018	3.6	2019	1,989,970	3.0
2010	1,672,785	3.5	2020	2,047,969	2.9

1.8 Outline

This research has been summarized in five chapters, Chapter 1 describes the background and the purpose that this study carrying of for. Chapter 2 contains the history of several studies related to current research in the name of literature review. All material properties and the methods that implemented during the numerical work are included in Chapter 3. Dealing with the results obtained from computer soft wares are included in chapter 4. At the end, Chapter 5 includes the conclusions from the conducted tests through this study and the recommendations for next studies and researches.



CHAPTER 2

LITERATURE REVIEW

2.1 Studies on water quality.

In preparing the study, the researcher relied on many studies on water quality in addition to studies on computational computing, and they were arranged according to their importance and relevance to the subject of the study. There are many studies that dealt with the issue of water quality, and the researcher mentions (5) of these studies, for example, but not limited to: -

a) Al Bohissi, N. (2015). Management of Brine from Seawater Desalination Plants in Gaza Strip: Deir AL Balah STLV Plant as Case Study.

This thesis was directed towards evaluating the efficiency of groundwater used to irrigate crops in Deir al-Balah governorate, where twelve agricultural wells were selected for this purpose, with the analysis of its groundwater in the laboratory in terms of the following variables (chloride, nitrate, electrical conductivity) The study aimed to highlight the reality of the groundwater exploited in the irrigation of crops, and to show the impact of the quality of this water on crops and to predict the future of agriculture in Deir al-Balah governorate in the light of reality current groundwater The results showed that the well water contains a high concentration of salinity, which makes it unsuitable for irrigating many crops, which resulted in changes in the crop composition at the governorate level, as some crops disappeared.

b) Abdullah, Mahmoud. (2013). Assessment of Water Quality of Drinking Water Wells in Khan Yuns Governorate of the Year (2000-2012).

The study evaluated the quality of drinking water from wells in Khan Yuns governorate, and 26 samples of well water were taken and analyzed for the year 2011 and 2012 distributed over the municipalities of Khan Yuns governorates in addition

to the data of the Ministry of Health for the same wells from 2000-2011. It was found through the study that 84.6% of the study wells do not comply with the standards of the Health Organization the global level in nitrate concentration, and 76.9% of the governorate's wells also do not comply with international health standards in the concentration of chloride element.

c) Weinthal, E., Vengosh, A., Marei, A., Gutierrez, A., & Kloppmann, W. (2005). The water crisis in the Gaza strip: Prospects for resolution. *Groundwater*.

The study aimed to clarify and reveal the Israeli practices represented by its laws to implement the policy the robbery of water resources in the Gaza Strip during the occupation period, and identifying the water conditions in the Gaza Strip the Gaza Strip, such as the quantity, use and quality of water, and highlighting the huge losses incurred by the agricultural and industrial sector as a result of the shortage and deterioration of water quality, highlighting the expected dangers of the water problem. The study also dealt with many problems, the most important of which is the increase in water from the tank the groundwater and the resulting disturbance in the water situation in the Gaza Strip, the increase in population numbers and its high density as for the area, it led to an increase in water consumption and use, in addition to the great waste of water due to the failure to benefit from rain water, in addition to the population's lack of awareness of the water crisis in the Strip. Highlighting and clarifying the relationship between the political dimension and water security in the Israeli policy to control Palestinian water resources.

d) Ramadan, Abu Ras. (2012). wastewater and Its impact on the aquifer in the Gaza governorate: a study in environmental geography.

The study dealt with the issue of wastewater in Gaza Governorate, in particular, resulting from the phenomenon of cesspits, their places of spread, their concentration in the study area and their impact on the aquifer. The study showed statistically the quality of chemical and biological groundwater in wells, it was found that the rate of nitrate is affected by the intrusion of wastewater, and therefore it rises in most of the wells of Gaza Governorate, where the percentage of nitrate reaches more than 200 mg/liter in most wells, and the rate of chloride is 50 mg/liter in most of the wells. This rate exceeds the standard recommended by the World Health Organization,

which is set at 250 mg/L This is due to the tyranny of sea water on the aquifer, due to its low level, and in terms of biological pollution, the study showed that most of the groundwater wells in the study area are contaminated with bacteria total Calform, where the percentage of contamination with these bacteria is up to 100 Calform, which is defined by the World Health Organization as 3 Calform.

a) Yassin, M. M., Amr, S. S. A., & Al-Najar, H. M. (2006). Assessment of microbiological water quality and its relation to human health in Gaza Governorate, Gaza Strip.

The study aimed to identify the validity of water quality in the North and Central governorates, to identify the causes and sources of water pollution and their role in the pollution of the aquifer, and to throw light on the incidence of water-related diseases The study deals with microbiological pollution in the waters of the northern and central governorates of the Gaza Strip, and the danger of this pollution to human health, as microbiologically polluted water is a source of infection for many diseases as adopted

The study on the reports of the Ministry of Health in counting the number of people infected with the diseases related to the study, to find the statistical relationship between microbiological contamination and the incidence of diseases for the study.

Summary of previous studies:

The researcher reviewed ten previous studies, and these studies were presented in a scientific order according to the date of their publication, the following is a comment on those studies and the location of the study from these studies: -

It is clear from the previous studies that they were partial studies or dealt with the subject of the study in a different way directly through the topics that have been explained where some studies focused to shed light on the applied importance of geographic information systems in extracting water quality maps while focus others on the possibilities offered by cloud computing and ways to benefit from them in many fields Therefore, this study was distinguished from previous studies by highlighting the reality of groundwater and showing the extent of the impact of the quality of this water in all aspects of life It explained the causes and sources of water pollution and its role in pollution of the aquifer based on geographic information

systems (GIS) in assessing the quality of groundwater "drinking water" in the Gaza Strip. This study was also distinguished from previous studies with the participation of the public on the problem of groundwater "drinking water" by creating a local website to make it available on the World Wide Web (Internet) for easy follow it up. Despite the diversity of the topics of the previous studies, their few were of great benefit to the subject of the study and highlight the need for further studies of water quality and cloud computing in all its forms to evaluate the quality of groundwater.



CHAPTER 3

METHODOLOGY

3.1 Introduction

There are multiple methodologies used in scientific study, and each method meets the requirements of a particular stage in the study, and this study will depend on the following methodologies, as shown in Figure 3.1:

- ❖ **Descriptive methodology:** This methodology was used to identify the characteristics of the Gaza Strip with the aim of finding the relationship between human factors and the nature of the place where water pollution is concentrated.
- ❖ **Historical Methodology:** To study the evolution and change in the volume of water pollution over the years covered by the study.
- ❖ **Applied Methodology:** Which will be based on (GIS) software (ArcGis10.1) in representing the stages the study is going through, and creating a website to raise awareness and community participation in pollution.
- ❖ **Analytical Methodology:** Where the data entered will be analyzed and the extent of the problem determined to identify the direct and indirect causes affecting the volume of water pollution, and the stages will be applied as follows:

- **The stage of data and information gathering**

- 1-Determining the most important pollutants in the pumping wells in the sector.
- 2-An aerial photo of the Gaza Strip in 2014.
- 3-Digital mapping of the Gaza Strip using (GIS) and projecting the coordinates of wells (municipal wells 145 wells) distributed over all the governorates of the Gaza Strip.

- **Data Entry and processing Stage**

- 1-Preparing a spatial database for pollutants by entering the data collected on those wells.
- 2-Entering wells with exact coordinates and documenting them on the aerial image.

- **Data Analysis Stage**

The entered data will be analyzed using tools (GIS Arc), which will include analysis and spatial query for any metadata as follows:

- 1- Using the program (GIS Arc10.1) in the production of various maps.
- 2- Using the (Analyst Spatial) in the (GIS Arc10.1) software to processing and analysis of the maps.
- 3-Using (Google Earth 4.5) software to create maps and make useful of aerial photographs of the study area.
- 4- Using Microsoft Office software in analysis and output.

- **Show Data and Results:**

- 1- Evaluation of the study problem in the sector.
- 2- Comparing that problem over the past and present years.
- 3 - Compare it to what is permitted according to the World Health Organization.
- 4 -Using the tools of the software (ArcGIS) to predict the size of the problem that the pollution will reach over the coming years, if appropriate solutions are not developed and implemented.

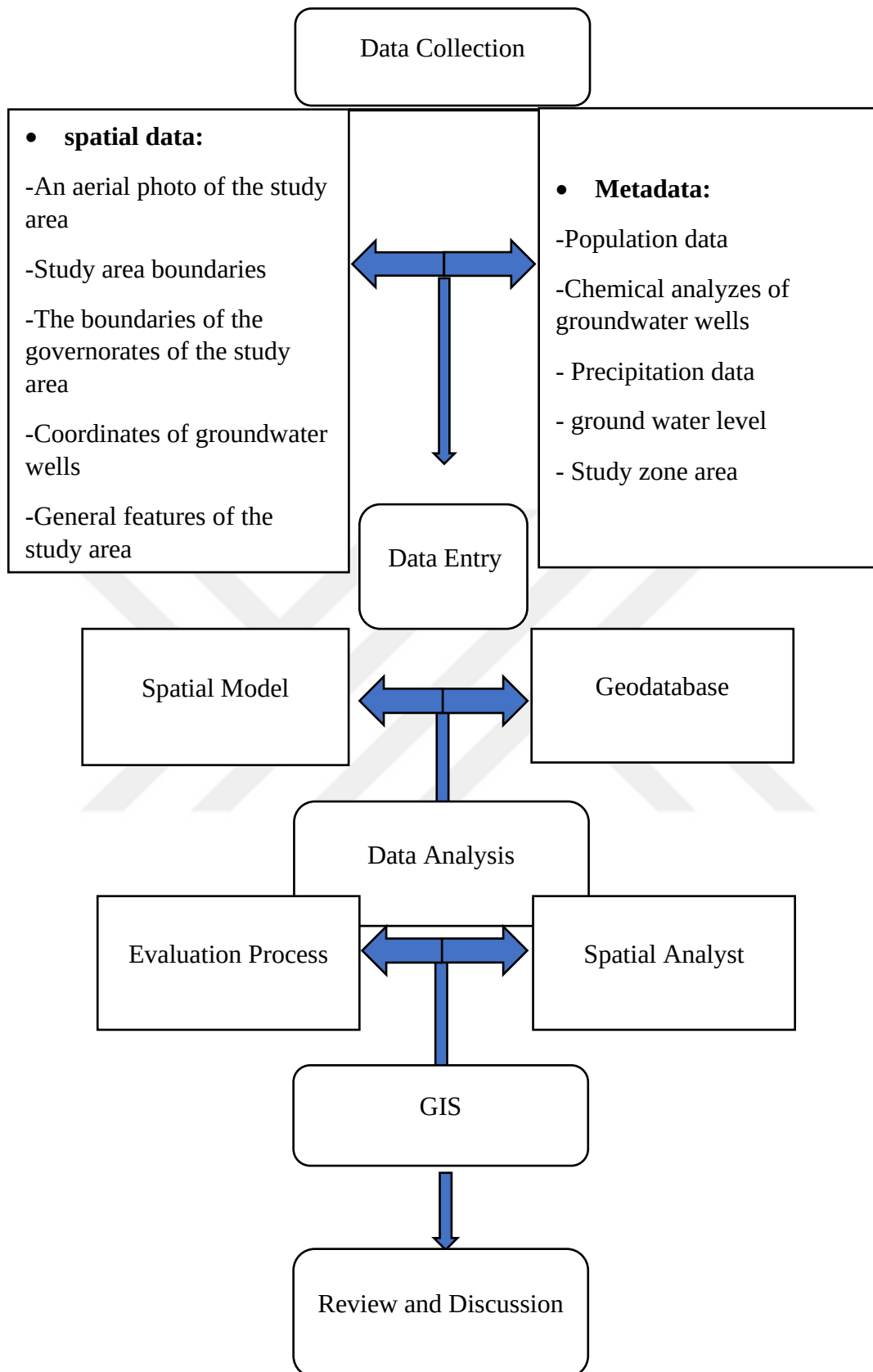


Figure 3.1 Methodology

3.2 Groundwater in the Gaza Strip

3.2.1 Groundwater Concept.

Groundwater means storing water that permeates to the surface of the earth in rocky layers Porosity under the surface of the earth (Faour and Fayad ,2014), and when this water collects in those layers in quantities sufficient for extraction and use, it is called underground reservoirs "Groundwater".

3.2.2 The Importance of Water in The Gaza Strip.

The Gaza Strip relies heavily on groundwater to meet the needs of the population, due to the absence of fresh surface water, such as rivers and lakes Groundwater is used in many areas, the most important of which is that it is considered a source for drinking and domestic use, as well as for agricultural consumption and industrial, where water after air is considered one of the most important components necessary for human life and safety, and as a result of the increasing demand for the water of the aquifer, the water stock in the aquifer has decreased, and with the increase in pumping from the aquifer, it is expected to further deteriorate the aquifer in the coming years, as a natural result of the increase The large population and its various water needs.

As mentioned previously, the Gaza Strip lacks sources of surface water such as rivers or lakes, and the temporary run-off of surface water, which is caused by rainwater in the winter season, the main source of surface water that does not last long, and there are some potential sources of surface water, such as the running water in the valleys, which collects in small valleys, the most important of which is Gaza river, which is one of the largest valleys in semi-arid Palestine in terms of area , where the length is from east to west in the Gaza Strip is about 9 km, and its area is estimated within the Strip 29.4 km² (Abd Rabou and Muhaisen, 2008), and it is considered amount of its water is small and may reach 20 million cubic meters annually, or decrease to 2-3 million cubic meters annually, depending on the amounts of rainfall in the water basin of the valley and according to the Israeli authorities control over the waters of the valley (Al Bohissi , 2015).

Note that the Israel authorities erected many barriers and dams to limit the flow of water in the valley and its access to the Gaza Strip, which led to the drying up of the lowest part of the valley in the Gaza Strip, except for the period of heavy rains in the

winter season, and thus the valley became a place for sewage disposal into the stream Down to the Mediterranean Sea (Al Bohissi, 2015).

3.2.3 The Groundwater Aquifer And The Amount Of Consumption In The Gaza Strip.

The coastal aquifer is the only source to meet the various water needs in the Gaza Strip, and it represents part of the coastal aquifer in Palestine, which extends from the Carmel Mountains in the north to the Sinai Peninsula in the south (Al-Yaqoubi,2011), with a length of approximately 220 km, and from alkhalil mountain range From the east to the Mediterranean in the west, it is about 15 km wide, and its thickness in the Gaza Strip ranges from 100 meters in the south to 180 meters in the north from the west, and from the east, its thickness ranges from 50 meters in the south to 60 meters in the north The current water reserve of the coastal aquifer in the Gaza Strip is estimated at about 4500-6500 million cubic meters (Aish,2013).

3.2.4 Ground Water Level.

The excessive consumption of groundwater in the Gaza Strip through various uses with the lack of adequate compensation for the aquifer is one of the reasons that led to a significant decrease in the water level in the aquifer, not to mention the large increase in population numbers in the Strip and their increasing need for groundwater Figure3.2 shows the massive withdrawal from groundwater wells during the years (2005-2014) in the Gaza Strip, according to the reports of the Water Authority.

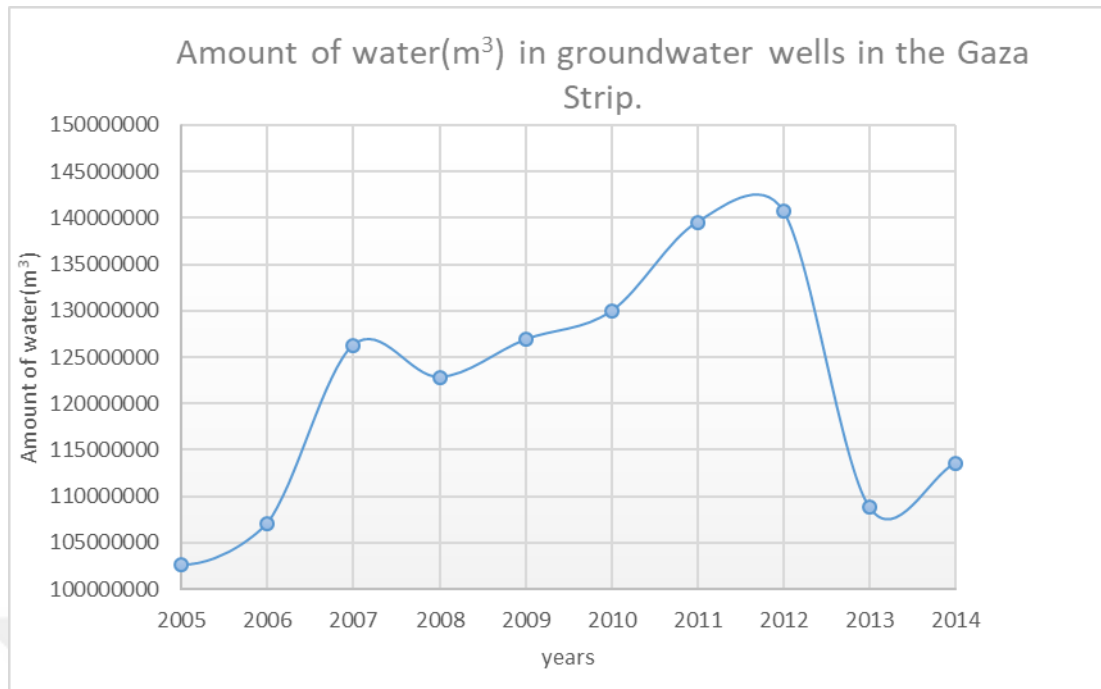


Figure 3.2 Withdrawal rate from groundwater wells in the Gaza Strip (2005-2014).

The unbalanced hydrological situation between the withdrawal and feeding of the coastal aquifer has caused serious problems, including the drop in the water level in the reservoir and the deterioration of its water quality. The problem occurred during the period from 1935 to 1971 (Al Bohissi, 2015), and the reason was due to several factors, including the influx of refugees into the Gaza Strip, in addition to the natural population increase, and agricultural expansion, all of which affected consumption rates, and consequently the water level, and the problem kept getting worse, and in 2014, analyzes proved that the level had fallen more than 8 meters below sea level.

3.2.5 The Problem of Groundwater Pollution.

The World Health Organization (WHO ,2015) defines water pollution as any change in the elements in its composition directly due to human activity, which makes this water less suitable for the natural uses designated for it or some of it. And in another definition of water pollution, it is “the changes that occur in the natural, biological and chemical properties of water, which make it unfit for drinking, or for domestic, industrial and agricultural uses” (Attaf and Omara ,2014).

The Groundwater Problem is Summarized as follows:

- a) Chemical pollution:** The continuous increase in salinity in the coastal aquifer of the Gaza Strip during the past four decades is due to the increasing depletion and thus the overlap of Sea water, in addition to the pollution caused by wastewater,

in addition to operations agriculture, fertilizers and pesticides, where salinity covers 70% of the water bearing layer in the Gaza Strip, and the average annual rate of increase in the salinity of drinking water is about 10 mg/liter annually. The last ten years to 40 mg/L per year (Authority, 2012).

One of the most important manifestations of chemical pollution is the chloride pollution, which reached the average salinity in 2015 was 1300 mg/L and a maximum of 10 mg/L, as for nitrate pollution, the average concentration of nitrates was 130 mg/L and a maximum of 380 mg/L, with reference to the standards set by the World Health Organization (Nitrate = 50 mg/L, Chloride = 250 mg/L), meaning that the level of pollution exceeded international standards by nearly three times, and these rates of aquifer water pollution indicate serious indicators.

- b) Quantity problem:** The Gaza Strip suffers from water scarcity, as the per capita share in the Gaza Strip is 290 cubic meters annually, which is less than a third of the value of the criterion that classifies countries as suffering from water scarcity, as there is an assessment by the World Health Organization stating the countries that suffer from water scarcity are the countries in which the amount of water per capita is less than 1000 cubic meters annually, (WHO, 2015). It should be noted that the coastal aquifer in the Gaza Strip suffers from continuous depletion and a deficit accumulated, the severity of which has increased in recent years, as the aquifer relies for its water recharge on the annual rainfall that gives it 20-40 million cubic meters, in addition to the water obtained from the natural side flow of water that moves from the east to the west, which is estimated annually 15-20 million Cubic meters, this means that the total annual supply to the aquifer is estimated at 70 million cubic meters. In contrast, about 220-200 million cubic meters of water are pumped from this aquifer, meaning that the deficit is estimated at about 140 million cubic meters (Yassin, 2006).
- c) Biological pollution:** The water problem in the Gaza Strip was not limited to a shortage in quantity and chemical pollution. Most studies indicate that groundwater is contaminated with parasites, viruses and bacteria, or what is called microbiological pollution (Melad, 2002).

3.3 Sources of water pollution in the Gaza Strip

There are many pollutants that reach the aquifer directly, such as the intrusion of sea water, or indirectly, such as the intrusion of sewage water into the soil, reaching the surface layers bearing unreserved water. The most important sources of water pollution in the Gaza Strip are summarized as follows:

3.3.1 Waste Water.

Waste water contains many organic, inorganic and microbial pollutants. Radioactive, thermal, and organic, inorganic and microbial pollutants are present in the wastewater in the form of leakable materials, suspended and dissolved materials in the form of a colloid. Wastewater and untreated water represent about 90% of the total wastewater in the Gaza Strip. And there are two main methods of wastewater disposal: sewage networks and cesspits, where sewage networks cover 60% of the dwellings, while 40% of them depend on cesspits (Authority, 2012). Water enters the underground aquifer, either by leaking cesspits or through sewage by reaching the sea and finally to its overlap with the water of the aquifer due to the low level. Not to mention the many diseases and microbes in wastewater that affect human health, including:

- a. Bacteria:** One of the common pathogens found in wastewater, it is of the genus *Salmonella* and causes internal fever and acute intestinal infections, including typhoid.
- b. Parasites:** including:
 - 1. Worms: including infectious worms such as scabies and tapeworms.
 - 2. Viruses: There are more than 100 types of them that are capable of causing infection. They are secreted from the infected person through water, including the hepatitis C virus.
 - 3. Sewage contains many toxic, heavy and rare elements that affect human health, such as (lead - zinc - boron - cadmium) and the reason for its presence is industrial wastewater where it is not separated from the household (Mogheir, 2005).

3.3.2 Fertilizers and pesticides.

The increasing demand for food has led to the use of different types of fertilizers, pesticides and agricultural fertilizers to increase the fertility of the available soil, with

the aim of increasing production of different crops. Because of the use of these materials and fertilizers in an unstudied manner, a large part of them dissolves in irrigation water and agricultural drainage and over time reaches the groundwater in the ground, thus raising the proportion of both nitrate and phosphate compounds in this water. I summarize here two types of dangerous pollutants:

1-Chemical Fertilizers: Pollution of the aquifer water with chemical fertilizers used to feed crops poses a great danger that leads to the destruction of aquatic ecosystems, and it appears through the use of these fertilizers that they may reach some water bodies close to agricultural lands through the process of fertilizing and irrigating them (Brisman,2007).

2-Chemical Pesticides: These pesticides contain a large group of different chemicals, and they are complex structures that have multiple characteristics according to their types that are used in the fight against agricultural insects in farms and fields, as well as house insects that transmit diseases (Sithole and Guy,1987).

It should be noted here that more than 90% of the insecticides do not reach and do not settle on the pest to be controlled, but reach the environment. This access is related to several factors, including the ability of the pesticide to survive and the movement of the pesticide or its final fate. After using the pesticide, it is exposed to loss on the surface of the soil. Or seepage into groundwater, and this depends on the solubility and absorption of the pesticide, as the pesticide dissolves or has a high degree of absorption tends to stay near the surface and is subject to surface loss and that pesticides with a high degree of solubility or dissolution have a degree low absorption characterized by a high ability to leaching and sedimentation through the soil, so the pesticides, after being used in the field, will be destined for the following possibilities: Loss by volatilization, transition, transformation, decomposition, degradation, or chemical reaction with the soil (Qassim, 2018).

3.3.3 Solid Waste and Its Types.

Solid waste is no less effective in polluting the aquifer water than waste water, as it contains sap that carries a high concentration of heavy metals and toxic substances, which if it reached the aquifer, spoiling its water. Where the chemical analyzes of the

Water Authority in the Gaza Strip during the past years proved the condition of groundwater in many wells, some of which are located near waste dumps, and by focusing on the changes in the elements of nitrate and chloride in groundwater, we find a significant increase in the percentages compared to international health standards as shown in the appendix (1) Concentration of elements in groundwater wells in the Gaza Strip.

3.4 Geographic Information Systems (GIS):

The importance of GIS applications in the use of the land is due to the fact that it is an effective and modern way to deal with the huge amount of data; It is characterized by a high ability to analyze data, which helps planners to reach correct decisions that may be difficult to reach by traditional methods; This is because it is characterized by the feature of integrating information through linking or collecting a set of different data in different layers that can be dealt with automatically, and benefited from it without prejudice to its accuracy, validity or significance.

The power of analysis in geographic information systems is shown in storing data in more than one layer, Figure 3.3 in order to overcome the technical problems resulting from processing large amounts of information at once, as data processing in one layer gives better analytical ability than processing it in the entire system in addition to linking these layers to a table or non-spatial information related to the same teacher (Alqarni, 2020).

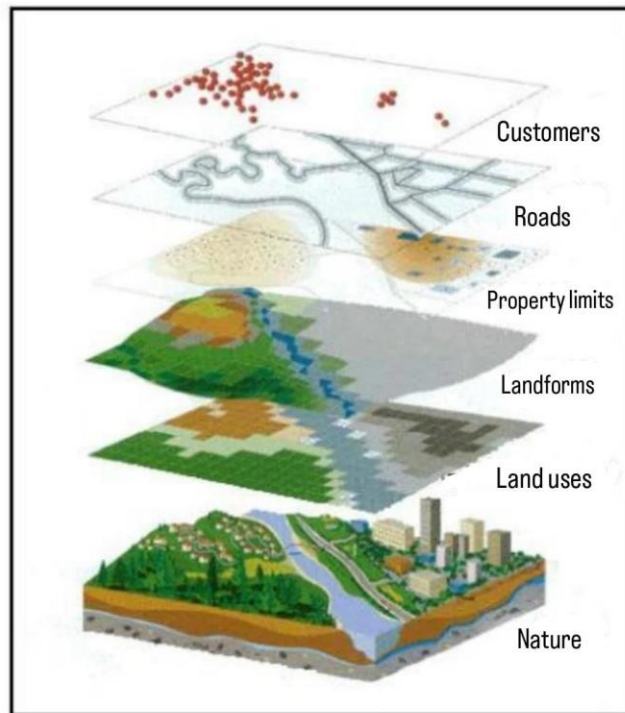


Figure 3.3 The concept of layers in GIS

3.4.1 General Background.

The beginnings of the emergence of geographic information systems in Canada go back to the project implemented by the Resource Department of the Canadian government, which bore the name of Geographical Information for Canada, which the Canadian government began implementing in 1963, and in 1970 the first conference on GIS was organized by the International Union of Geographers and with the support by UNESCO (Alqarni, 2020), and with the development of computers, they had a great impact on the development of this technology and moving from one place to another quickly, and before the end of the seventies, Jack Dangermond founded his own company, which bore the name of the Environmental Systems Research Institute (ESRI), which is the most important company in the history of GIS (Almasri,2008).

3.4.2 Definition of Geographical Information Systems (GIS)

There are many definitions of GIS, and the difference in definitions is due to specializations and cultures between people, the definition of ESRI and the definition of Smith, Parker, Field, Quinn, Borough and Devin, that it **(computerized maps linked to databases aimed at collecting, storing, retrieving, processing, analyzing, outputting and displaying data in order to make sound decision-**

making) (Basem, Sami Abu and Alfred ,2010), and the importance of geographic information systems lies in the importance of what they provide us with analysis and measurement of maps, conducting statistical operations, linking information, coverage, forecasting and forecasting.

3.4.3 Benefits of GIS

There are many benefits to GIS, including:

A- Reducing production efficiency time.

b- Improving the accuracy of the quality.

C- Reducing employment.

D- Reducing production time and labor.

C- cost reduction.

H - Enables a comprehensive view of the problem.

3.4.4 Basic Functions Of Geographic Information Systems (Al-Khalifa, 2010)

- a) Entry:** Entering information into a GIS is the first function of this system, whether this information or data is geographic information, descriptive information or statistics, and the entry process is the biggest obstacle in creating a GIS project, and the cost of entering information may reach 80% of the total cost of the project.
- b) Storage:** Consecutive steps to save it so that you can refer to it at any time, where the data is stored on temporary floppy disks or magnetic tapes in addition to hard disks.
- c) Processing and Analysis:** The processing process is one of the basic processes in GIS, and it can be said that it is one of the most important processes characteristic of GIS.
- d) Output and Data Presentation:** The outputs in GIS take various forms, including maps, graphics, tables, and written texts.

3.4.5 Components of GIS (Obermeyer and Pinto, 2007).

GIS consists of a set of elements that are composed and interconnected with the aim of achieving certain goals, which can be divided into five basic elements as follows:

- a) People:** One of the most important components of geographic information systems, People develop procedures and know the tasks of geographic

information systems Therefore, any person who uses GIS has the following conditions (experience and competence, ability to develop, creativity and innovation).

- b) Data:** Data is defined as raw facts in the form of numbers or letters that give a weak meaning in and of itself, as for information, it is the data on which certain operations were performed that changed its original form, and accordingly it can give a specific meaning Data is the heart of GIS, and its accuracy and availability affect the results of any query and analysis.
- c) Equipment:** Computers used for GIS must have high processing speed, ease of use, and a great ability to store data.
- d) Software:** Not only GIS software, but also database software and computer-aided design graphics.
- e) Analysis:** Analysis requires a good definition to give correct results for the problem or the subject of the study.

3.4.6 Applications of (GIS) in Assessing Water Quality.

GIS has many applications that cannot be counted, and every field of life can contribute to building an integrated system of geographic information systems and then benefit from its outputs and analyzes Jack Dangermond, founder of ESRI, states that GIS applications are limited only to the imagination However, it is not enough to mention all of these applications, and the study is sufficient to address the applications of GIS in assessing water quality, which are as follows:

- a)** It is used as a tool to raise the level of efficiency and performance of work and to improve the level of management in the process of monitoring underground reservoirs.
- b)** Building specialized maps, such as the map of the distribution of wells to the governorates, and the census of quantities Consumption.
- c)** Choosing the best site for the construction of underground wells.
- d)** Evaluation and analysis of pumping wells for the population.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Geographical Information Systems (GIS) is an important tool for integrating spatial data with other information. It allows for integrated data analysis, spatially representation, planning for resource development, environmental protection and scientific research. These capabilities make GIS a powerful tool for groundwater assessment. GIS not only measures the deviation in measured values by water quality (standards), but can relate groundwater quality to land use, soil properties, and other relevant information. In addition, GIS provides capabilities for creating maps that show the results of data analyzes geographical information systems were used to describe the relationship between water quality and all natural and human activities in the world In Palestine, it has been applied to a limited extent, but it is not well implemented for planning, managing resources and protecting the environment The main objective of this chapter is to use GIS to compare and monitor water quality data over the past years, and also provide a special model for the chemical properties of groundwater and create maps that can be viewed easily by the public and decision makers.

4.2 Modeling Discussion.

4.2.1 The Modeling and Mapping (GIS).

GIS applications were conducted according to data collected from several sources, and the aquifer in the Gaza Strip was evaluated within the modeling environment, using GIS, and after reviewing the data and sorting it by years, it was converted into GIS files, and a model was made to facilitate the analysis process and avoid repetition. Implementation of operations, and this modeling has clearly contributed to dealing with data.

4.2.2 Map Reference.

The basic map used in the study (digital data) was developed by the Ministry of Planning, the water authority, and the environmental quality authority in Palestine, and geographical references were made to the local coordinates (Palestine 1923 Palestine Grid).

4.2.3 Preparing Groundwater Quality Maps.

The data used in mapping and their chemical properties were obtained from the Palestinian Water Authority. The data for this study was based on periodic field work conducted by the Palestinian Water Authority for groundwater samples, and then the locations of groundwater wells were combined with data on water quality; To create spatial distribution maps, and produce digital maps of chemical elements affecting water quality, including the following elements: (No₃, CL, Na, K, Mg, SO₄, Hardness, EC, TDs, level Water), using the function of creating a geographical database in Map Arc).

4.2.4 Interpolate Raster.

It is concerned with Interpolate Raster as “the generation of areal maps from a set of data stored in points, where we use them to obtain unknown values” (Balakrishnan 2011), Figure 4.1 illustrating the process of deduction; The right part of the figure is a spatial map that was deduced from the points shown in the left part of the figure.

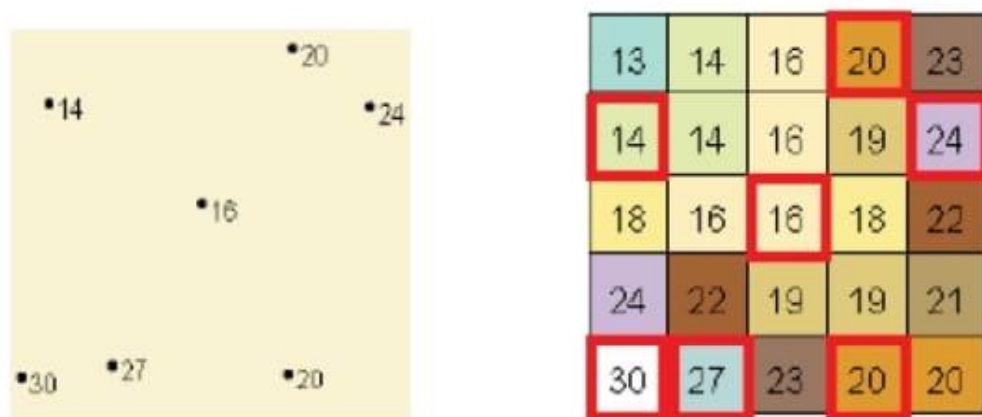


Figure 4.1 The generation processes\ Interpolation.

We use the Interpolation process when visiting every place to measure the level of groundwater, or the concentration of pollution in the water is difficult, costly or even dangerous. The process of deducing the maps allows knowing the missing values

from the measured values, by using mathematical functions, in general the basic default in spatial deduction are "points close to each other bearing values that are more close to each other than far ones". In other words: "Each cell that will be inferred will be from the cells next to it."

❖ **Interpolation Is Based On the Following Data:**

1. **Interpolation / generation processes:** It is Interpolation for unknown values that located between two or more known values. Figure 4.2, as the inference of the maps allows knowing the unmeasured values and generating them from the values that were measured by using mathematical equations.

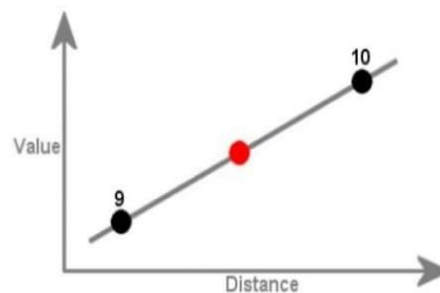


Figure 4.2 The interpolation processes

2. **Spatial Interpolation:** It is Interpolation for unknown values from a set (sample) of known and measured values distributed throughout the geographical area. Figure 4.3 as the distance between each cell of unknown value and the cells of the sample of known value contributes to the Interpolation and the sample points must be distributed Well over the geographical plot.

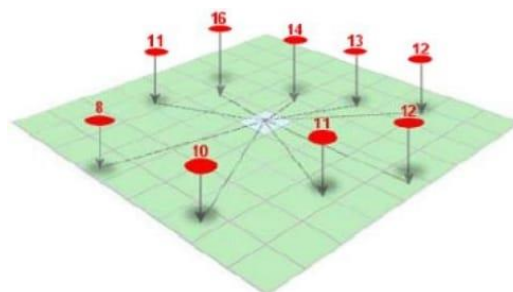


Figure 4.3 The spatial Interpolation processes.

3. **Sample size:** the larger the sample size, the greater the accuracy of the Interpolation, and the process takes longer.

❖ Interpolation Raster Methods

1. **Inverse Distance Weighted Interpolate (IDW):** This method is based on automatic correlation, meaning that “each point has a relationship to another, but the points close to each other are more closely related than the far ones.” If it rains in one area, the probability that it will rain in another area 100 meters away is more noticeable than if it rains in an area 300 meters away. Figure 4.4 shows the darker colored areas have a greater effect due to their proximity to the cell whose value is to be deduced.

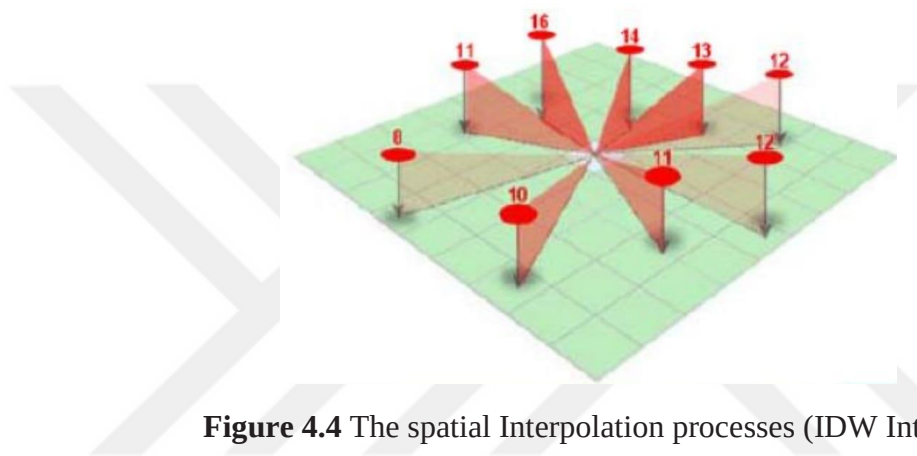


Figure 4.4 The spatial Interpolation processes (IDW Interpolation).

This method is used very efficiently when the researcher has a large number of points, and they are distributed uniformly, and this method does not calculate any data regularities, "in other words" if the researcher has a data set that expresses humidity, for example, and its value increases in the north for any reason, the surface generated from the process interpolation you will take the average of the values and will not reinforce this regularity in the values.

This method works in the process of interpolation that: the nearby points have a high effect, while the far points have a low effect, as this method cannot predict or deduce values higher than the highest value in the sample or less than the lowest value in the sample.

2. **(Spline) interpolation:** Unlike the first method (IDW), the (Spline) method does not use the arithmetic mean in the process of interpolation, but the deduced surface is flexible. It is like a piece of cloth that connects all the points Fig. 4.5.

This method is used when we want to deduce values that are higher than the highest value found in the sample points or less than the lowest value found in the sample points. There are several disadvantages in this way, the most important of which is, when the points are adjacent and significantly different in value, the Spline surface does not work as efficiently as required.

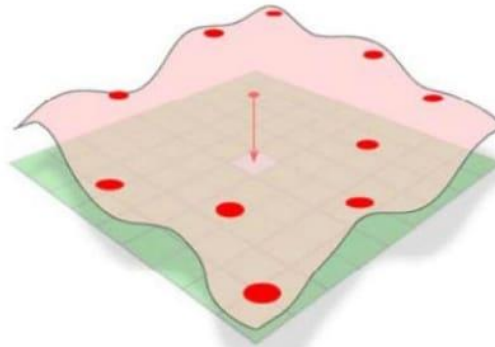


Figure 4.5 The spatial Interpolation (Spline interpolation)

3. **(Kriging) interpolation:** Very similar to the first method (IDW), where the method (Kriging) uses the arithmetic mean in the process of interpolation, but in a more complex way, as all the points enter into Calculate the mean (grid), as shown in Figure 4.6. In this method, values above the highest value or less than the lowest value can be obtained, unlike in the IDW method.

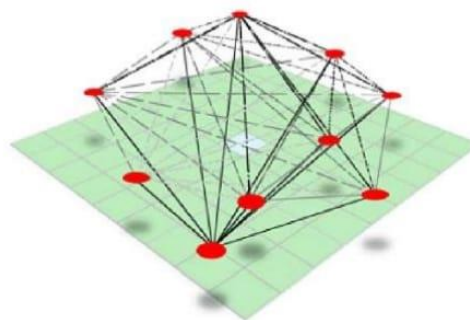


Figure 4.6 The method of Kriging Interpolation

The Inverse Distance Weighted (IDW) method was used in the analysis processes, because of its high efficiency when we have a large number of points, and they are distributed in a regular and consistent way, as this method is considered effective with surfaces with distributions related to distances such as water and noise, and it is also considered the only method (from The 3 methods) in which distance is taken into account, and this

method does not calculate any regularities of the data and reinforce it in the inferred values , as shown in Figure 4.7.

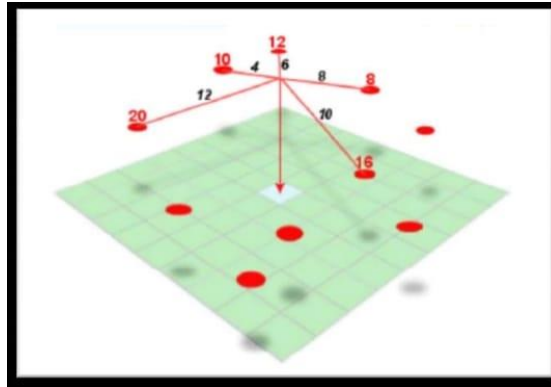


Figure 4.7 The method of Inverse Distance Weighted (IDW)

This method uses both the sample values and the distances that separate them from the point to be deduced in the process of interpolation. The nearby points have a large effect, while the far ones have a low effect. This method cannot predict or deduce values higher than the highest value in the sample or less than the lowest value in the sample.

4.3 Chemical Elements Affecting Groundwater in The Gaza Strip.

4.3.1 The Concept of Chemical Pollution.

Chemical substances in their gaseous, solid and liquid states, which are classified as effective, toxic, explosive or corrosive and may result in a danger to the environment and public health, whether alone or when in contact with other substances (Albloushy and Hiller Connell ,2019).

4.3.2 Chemical Pollution of Water.

Chemical pollution in industrialized countries has a greater impact than in developing countries, where people seem to pay great attention to toxic substances that may reach drinking water sources. There are about 765 substances detected in drinking water, including 12 substances considered cancerous, and 13 substances suspected of being Cancerous substances, and 59 substances that affect genes (McGrane,2016). The watercourse is considered polluted when the composition or condition of its water changes directly or indirectly as a result of human action, and thus its water becomes less suitable for uses in its condition Microbes are a source of contamination, making them harass or harm legitimate uses of life polluted water contains substances foreign to its natural component, which may be dissolved or

suspended solids, dissolved organic or inorganic materials, or microscopic substances such as bacteria, algae or parasites, which leads to a change in its natural, chemical or biological properties, making the water uninhibited Suitable for drinking or home consumption, it is also not suitable for use in agriculture or industry. We can define chemical pollution in water as the pollution in which the water becomes annoying as a result of the presence of dangerous chemicals in it, the chemical pollution of water is one of the most important and most serious problems facing modern man (Al-Shammari,2013).

4.3.3 WHO Standards (Chemical Properties).

It is the water suitable for drinking and domestic uses, and the water used in the food industries that conform in its characteristics to the requirements of the international standard, as shown in Table 4.1.

Table 4.1 Global Health Measures

Chemical Elements	Code	Maximum(mg/l)
Nitrates	NO ₃	50
Chloride	CL	250
Sodium	Na	200
Potassium	K	12
Magnesium	Mg	150
Calcium	Ca	200
Hardness	Hardness	600
Dissolved solids	TDs	1000

Reference: WHO,2016

4.3.4 Groundwater Pollution with Chemical Elements in The Gaza Strip.

The process of maintaining water quality requires periodic monitoring and routine analysis of water quality from a chemical point of table B.2, which is necessary to determine the degree of its pollution, and it means having a laboratory with a specialized staff in this field, as chemical pollution has many and varied sources, ranging from those Resulting from factory waste, or chemicals resulting from the agricultural use of pesticides and fertilizers, and the accumulation of these wastes in the environment surrounding those activities and then their descent to the lower soil layers and thus groundwater, and the possibilities of their transfer to more toxic substances and dangerous to human health when water is used for drinking, as well as its impact Negative effects on crops when used for irrigation.

4.4 Evaluation of Chemical Elements Using Geographic Information Systems GIS.

GIS technology provides an effective tool in analyzing and evaluating the degree of groundwater pollution; Therefore, this technology is important for decision makers in land reclamation, the Groundwater Authority, and the quality control of this water. The study aimed at evaluating groundwater and the extent of pollution in the Gaza Strip, knowing the areas prone to groundwater pollution, and providing knowledge of the factors and conditions that lead to the pollution of groundwater layers in the different regions of the Strip. The groundwater wells in the Gaza Strip were chemically evaluated, which amounted to 145 wells (municipal wells) as shown in Figure 4.8 from the period 2007-2015 using geographic information systems using the tool "Inverse Distance Weighted interpolation" (IDW) from tools of the Interpolation "Deduce cadastral maps" in the Map Arc program (according to Analyzes documented by the Environmental Quality Authority. Appendix No.1.

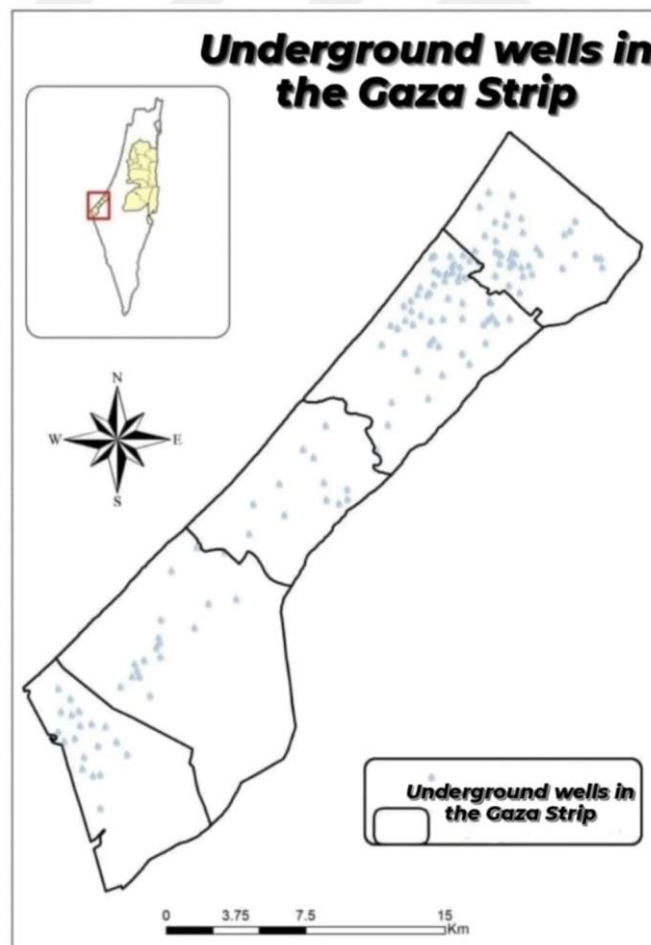


Figure 4.8 The locations of municipal wells in the Gaza Strip

4.4.1 Nitrate " NO_3 ".

The following analyzes in figures 4.9 to 4.16 show the percentage of nitrate in groundwater wells in the Gaza Strip over the previous years (2007, 2015), the degree of water pollution, and its compatibility with the standards of the World Health Organization. as it was found that the lowest percentage of water wells that comply with the standards of the World Health Organization for nitrate element was estimated at 11.7% in the year 2015, and the highest percentage of well water that complies with the standards of the World Health Organization for the element nitrate was estimated at about 26% in the year 2007, and this means that the pollution rate is increasing dramatically from year to year.



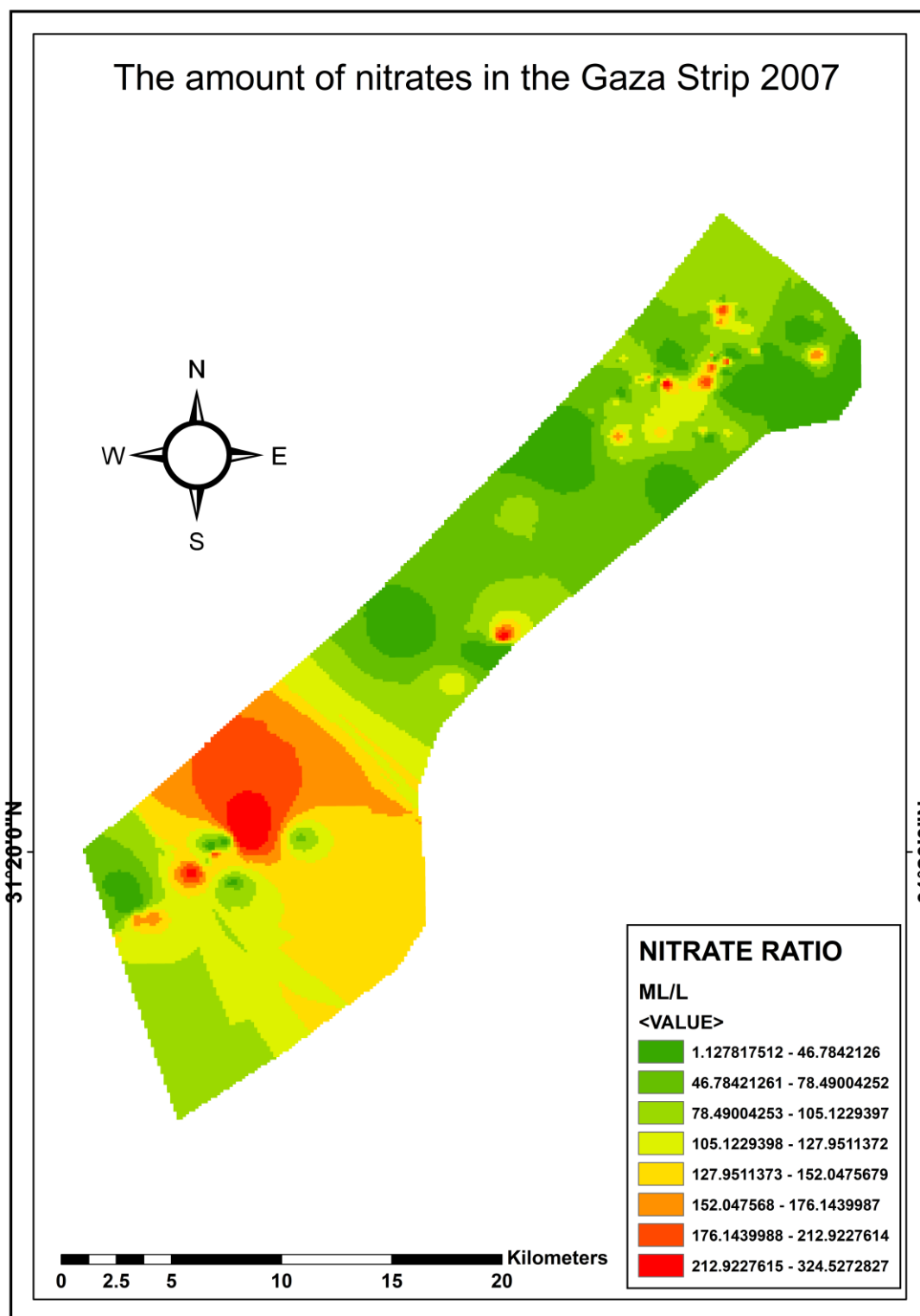


Figure 4.9 The nitrate rate in the Gaza Strip in 2007

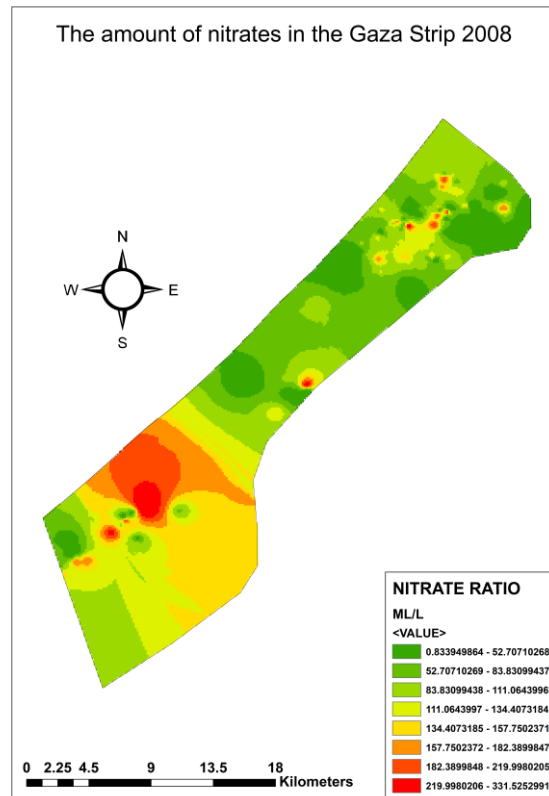


Figure 4.10 The nitrate rate in the Gaza Strip in 2008

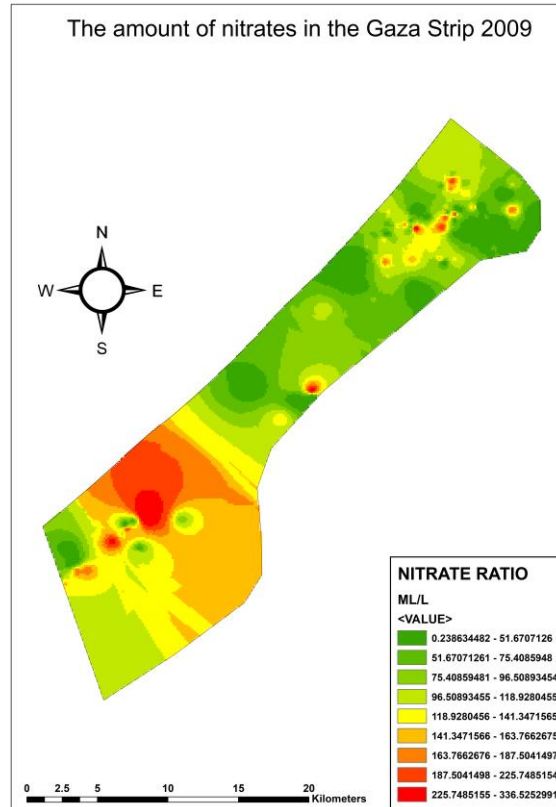


Figure 4.11 The nitrate rate in the Gaza Strip in 2009

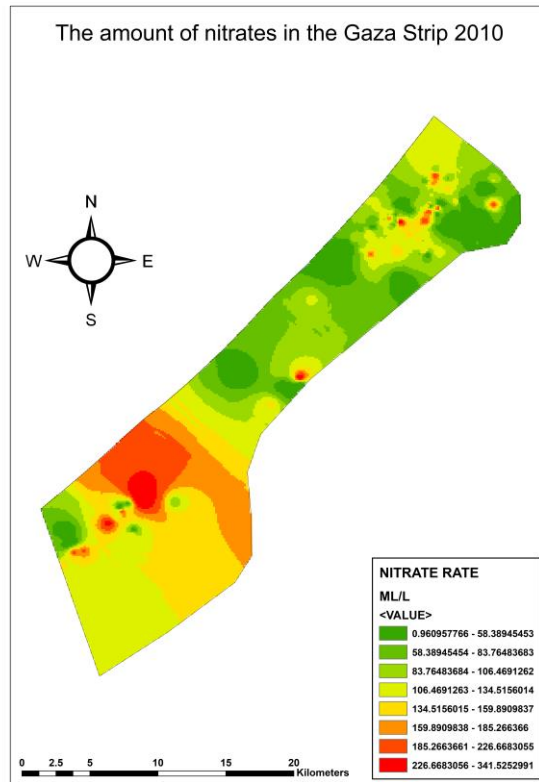


Figure 4.12 The nitrate rate in the Gaza Strip in 2010

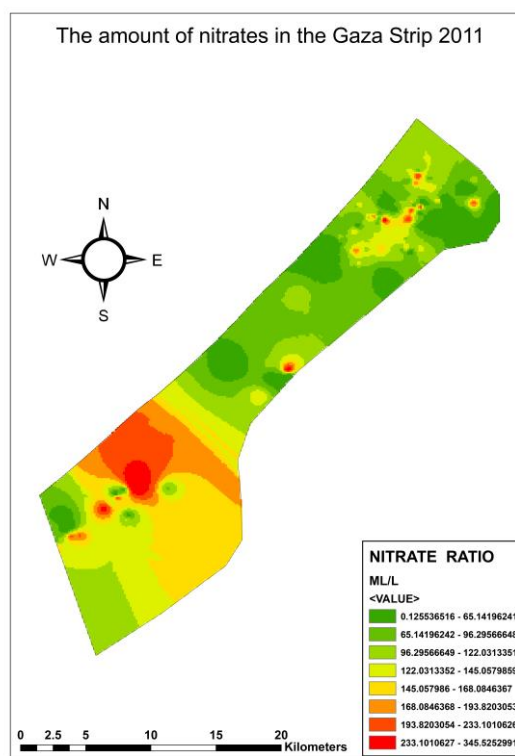


Figure 4.13 The nitrate rate in the Gaza Strip in 2011

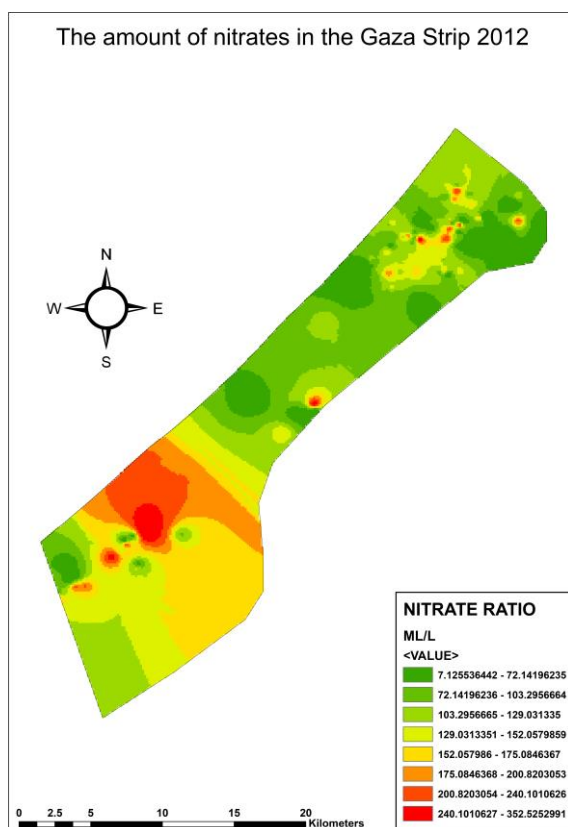


Figure 4.14 The nitrate rate in the Gaza Strip in 2012

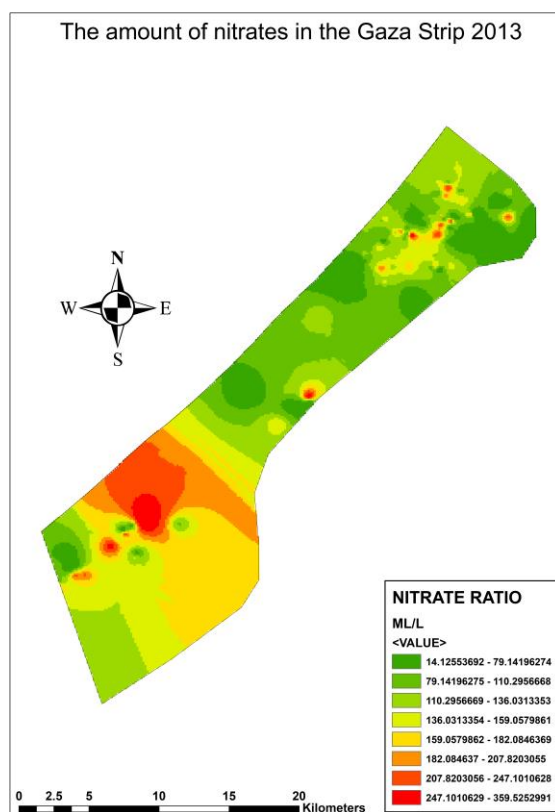


Figure 4.15 The nitrate rate in the Gaza Strip in 2013

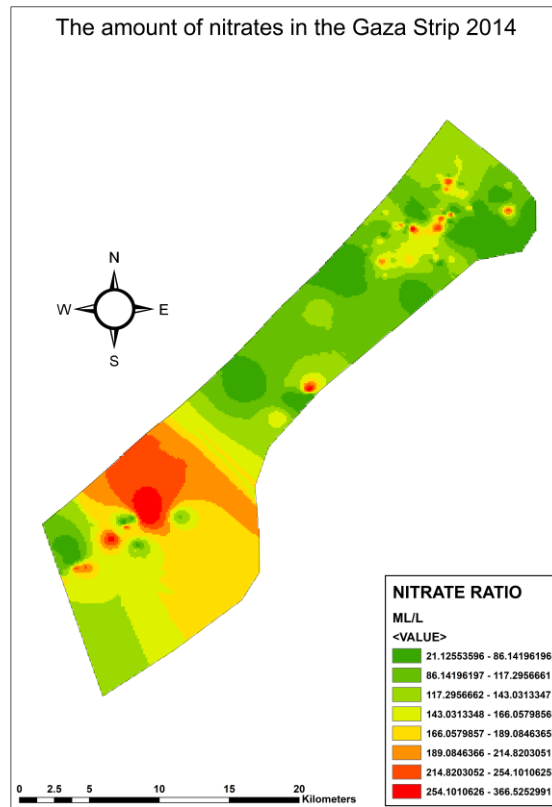


Figure 4.16 The nitrate rate in the Gaza Strip in 2014

Evaluation of the nitrate component for the governorates of the Gaza Strip 2015.

As mentioned previously, the average concentration of nitrates reached 105 mg/liter and a maximum of 450 mg/l, and with reference to the standards set by the World Health Organization for nitrates is 50 mg/l, meaning that the level of pollution exceeded international standards by almost three times, Figure 4.17. Based on the 2015 Water Authority data, the number of drinking water wells in the governorates of the Gaza Strip was monitored at 145, and wells that are subject to international standards for nitrate were extracted at the governorate level. It was found that wells that violates the standards are 32 out of 38 wells, meaning that only 6 wells. They are subject to international standards for the element nitrate, and the wells of the Gaza Governorate, totaling 64 wells, found that only 3 wells were subject to the international health standards for the element nitrate, and for the wells of the central Governorate, which numbered 9, it was found that only 3 wells are subject to the international standards for the element nitrate, and as for the wells of the Governorate Khan Yunis, totaling 15 wells, found only one well that meets international standards for nitrate Finally, wells in Rafah Governorate, totaling 18

wells, found that only 4 wells meet international standards for nitrate 17 out of 145 wells, meaning that the percentage of wells suitable for human use does not exceed 12% for nitrate Fig 4.18.

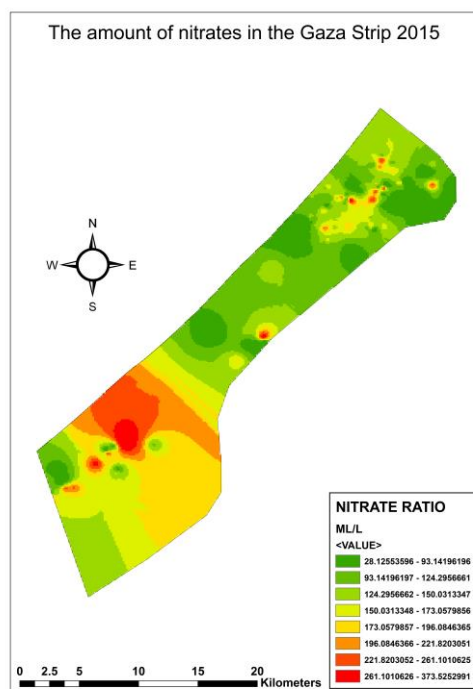


Figure 4.17 The nitrate rate in the Gaza Strip in 2015



Figure 4.18 The concentration of nitrates according to the standards of the World Health Organization (50 mg/L)

4.4.2 Chloride "CL".

The following analyzes in figures 4.19 to 4.26 show the percentage of chloride element in groundwater wells in the Gaza Strip over the previous years (2007, 2014), show the degree of water pollution, and its compatibility with the standards of the World Health Organization, as it was found that the lowest percentage of water wells that comply with the standards of the World Health Organization for chloride element was estimated at about 21.3% in 2015, and the highest percentage of water wells that comply with the standards of the World Health Organization for the element chloride is estimated at about 34% in 2007, which confirms that the percentage is constantly increasing from year to year.

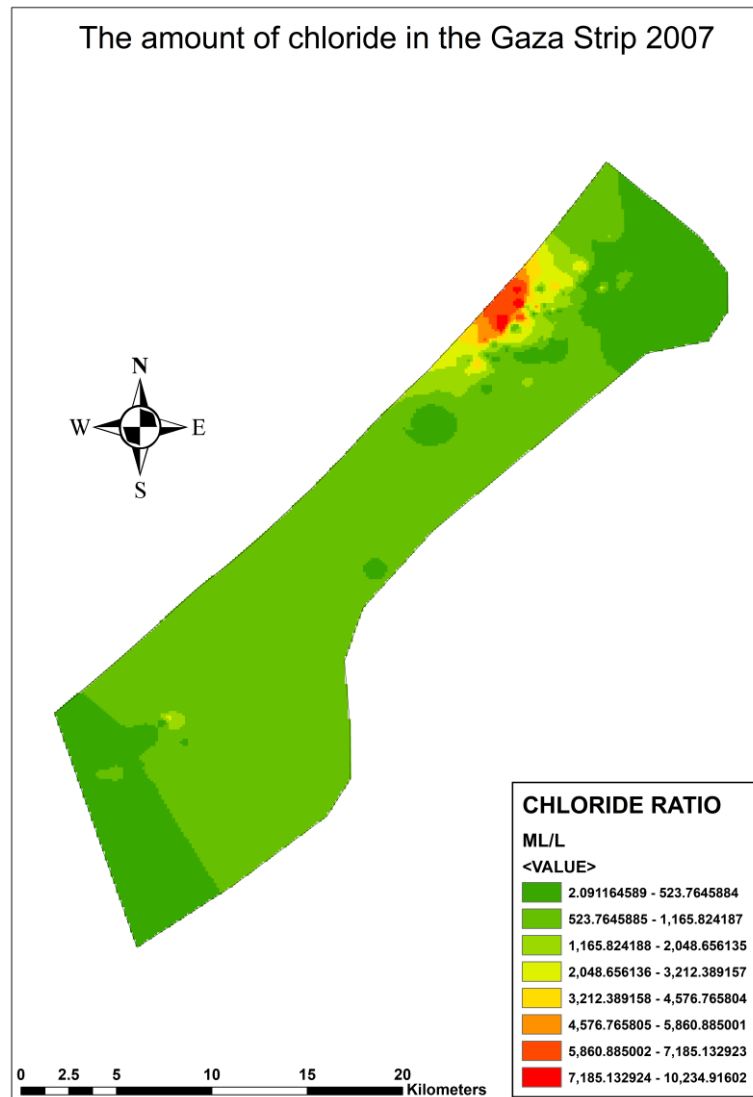


Figure 4.19 The Chloride rate in the Gaza Strip in 2007

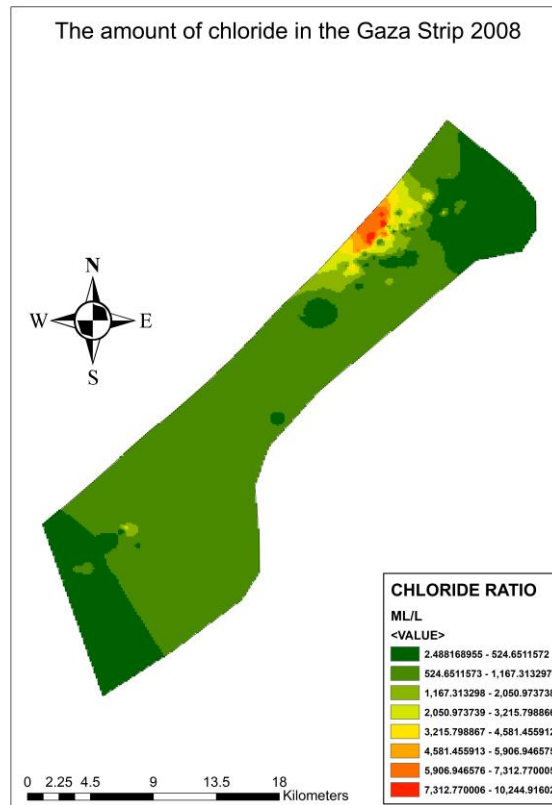


Figure 4.20 The Chloride rate in the Gaza Strip in 2008

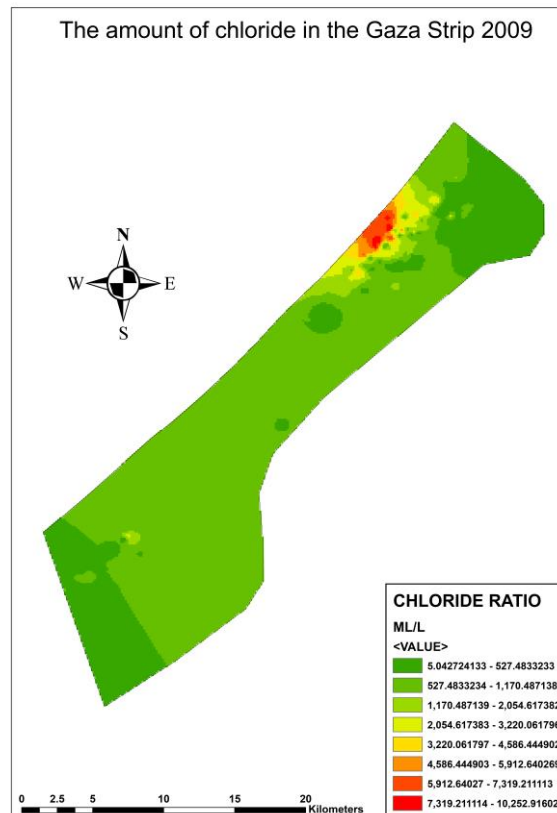


Figure 4.21 The Chloride rate in the Gaza Strip in 2009

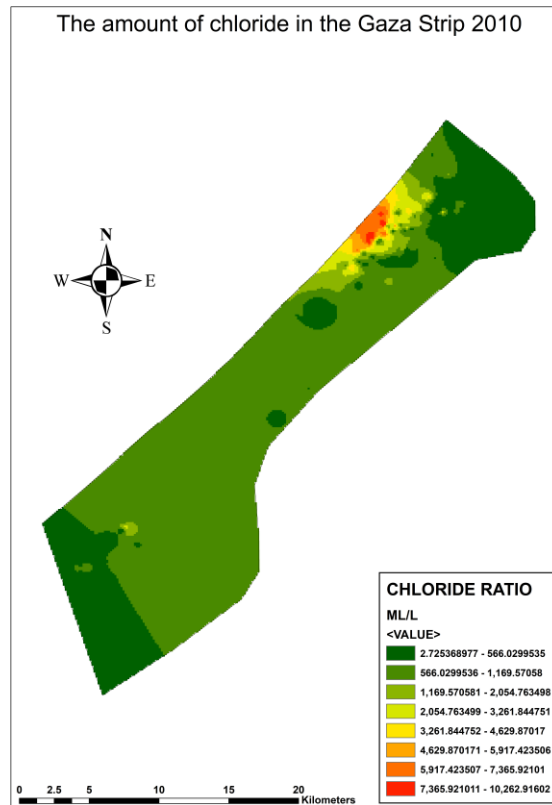


Figure 4.22 The Chloride rate in the Gaza Strip in 2010

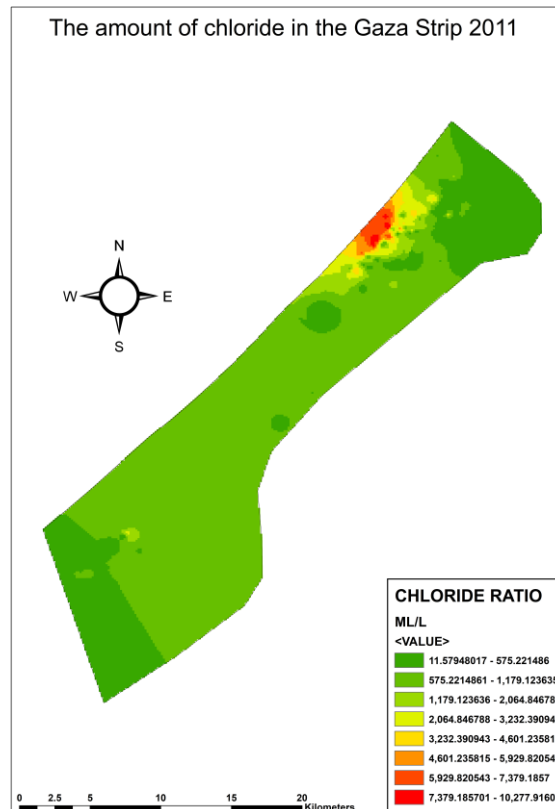


Figure 4.23 The Chloride rate in the Gaza Strip in 2011

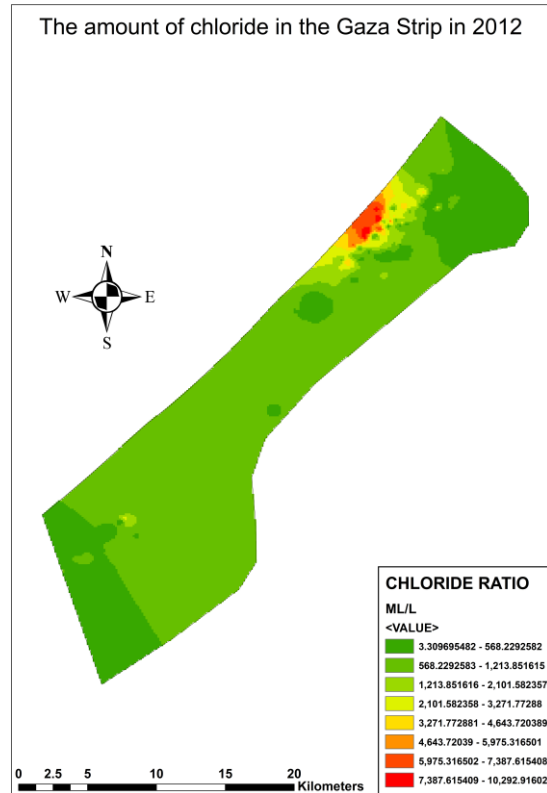


Figure 4.24 The Chloride rate in the Gaza Strip in 2012

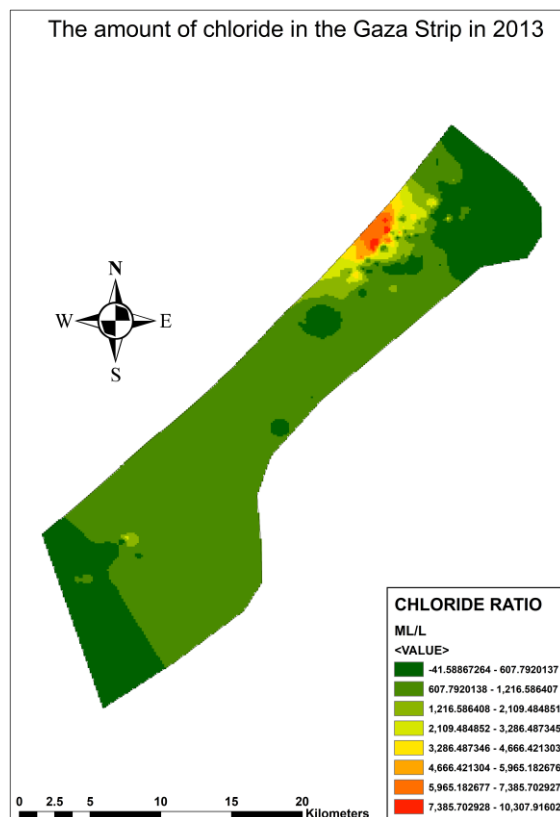


Figure 4.25 The Chloride rate in the Gaza Strip in 2013

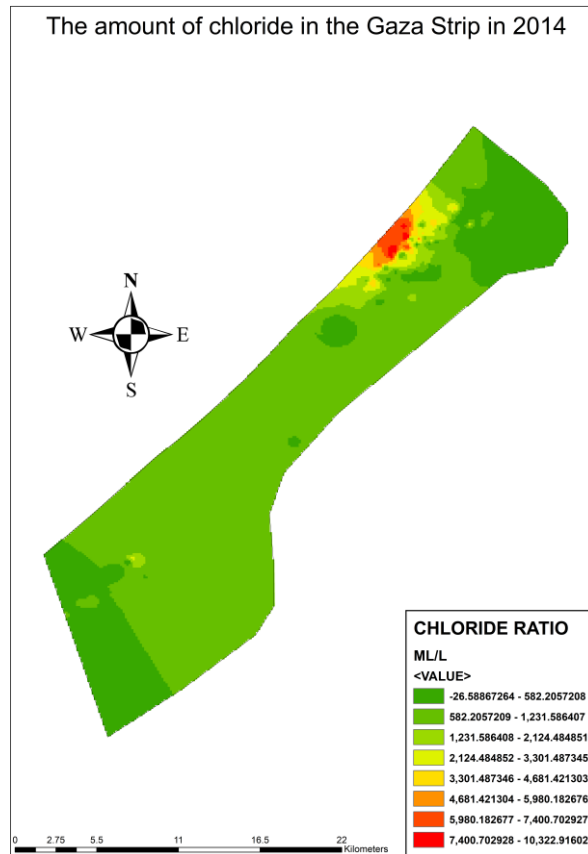


Figure 4.26 The Chloride rate in the Gaza Strip in 2014

Chloride assessment of the Gaza Strip governorates for the year 2015

The average salinity "chloride" for 2015 reached 1300 mg/l and a maximum of 10,000 mg/l, meaning that the level of pollution exceeded international standards by almost five times, Figure 4.27. Based on the data of the Water Authority for the year 2015, the number of drinking water wells in the governorates of the Gaza Strip was monitored and the wells that are subject to international standards for the element chloride were sorted at the governorate level, it was found that only 3 wells are subject to the standards. For central Governorate, it did not find any wells that comply with international health standards, and they numbered 9 wells, and Khan Yuns governorate had 15 wells. It was found that only 4 wells were subject to international standards for chloride, and finally, the wells of Rafah Governorate totaled 18 wells, it was found that only 3 wells are subject to international standards for the element chloride, we conclude from this that the number of wells suitable for human use does not exceed 31 out of 145 wells, with a percentage of 21.3% for the element chloride Fig 4.28.

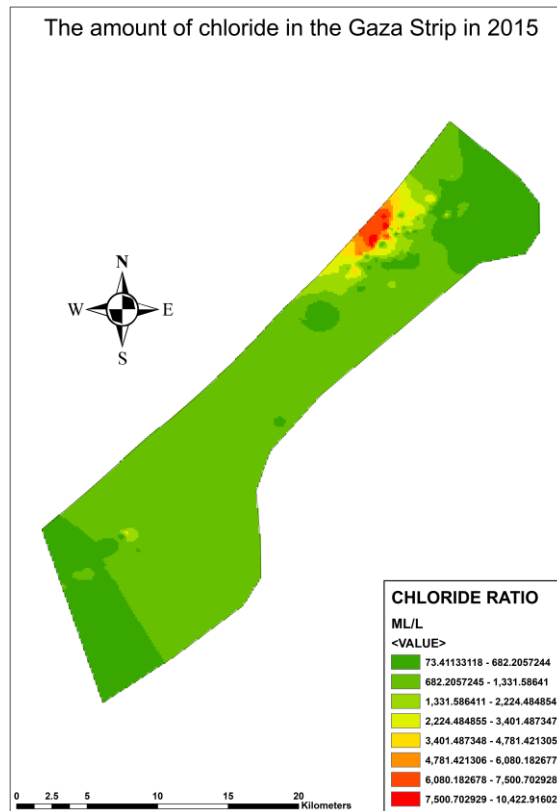


Figure 4.27 The chloride rate in the Gaza Strip in 2015



Figure 4.28 The concentration of chloride according to the standards of the World Health Organization (250 mg/L)

4.4.3 Sodium "Na".

The following analyzes in figures 4.29 to 4.36 show the percentage of sodium in groundwater wells in the Gaza Strip over the previous years (2007, 2014), show the degree of water pollution, and their compatibility with the standards of the World Health Organization, as it was found that the lowest percentage of water wells that comply with the standards of the World Health Organization for sodium element is estimated at 27.7% in 2014, and the highest percentage of water wells that comply with the standards of the World Health Organization is the element sodium is estimated about at 42.8% in 2007.

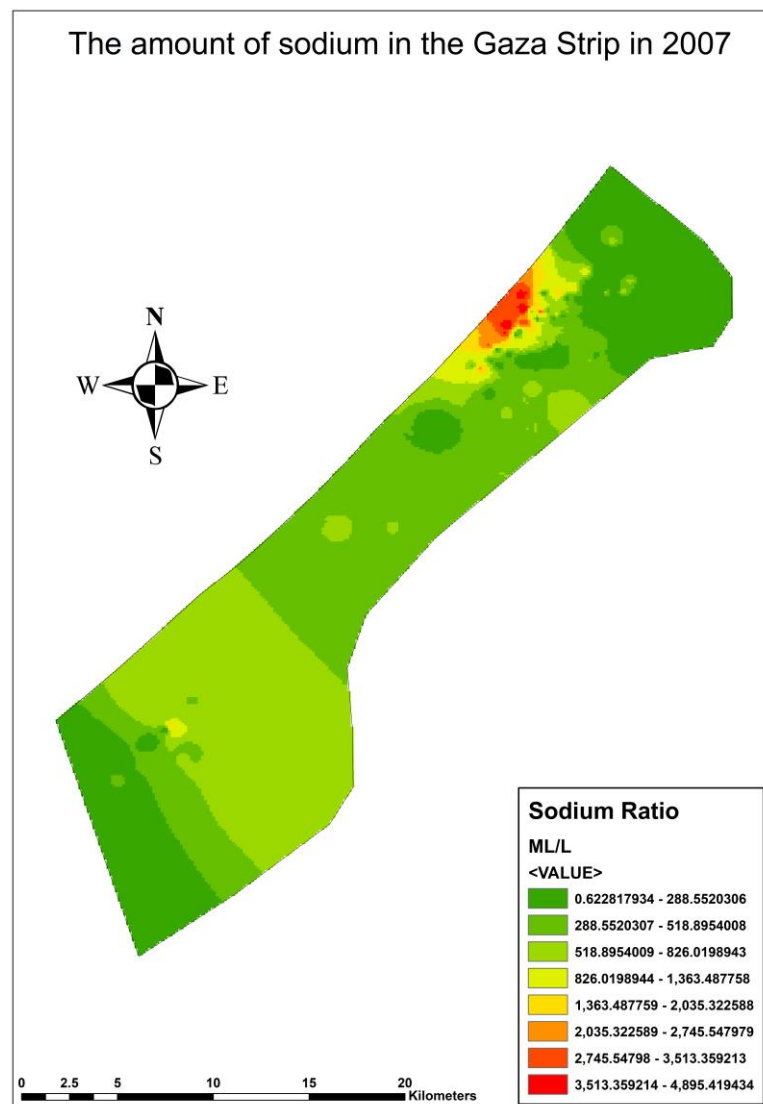


Figure 4.29 The Sodium rate in the Gaza Strip in 2007



Figure 4.30 The Sodium rate in the Gaza Strip in 2008



Figure 4.31 The Sodium rate in the Gaza Strip in 2009

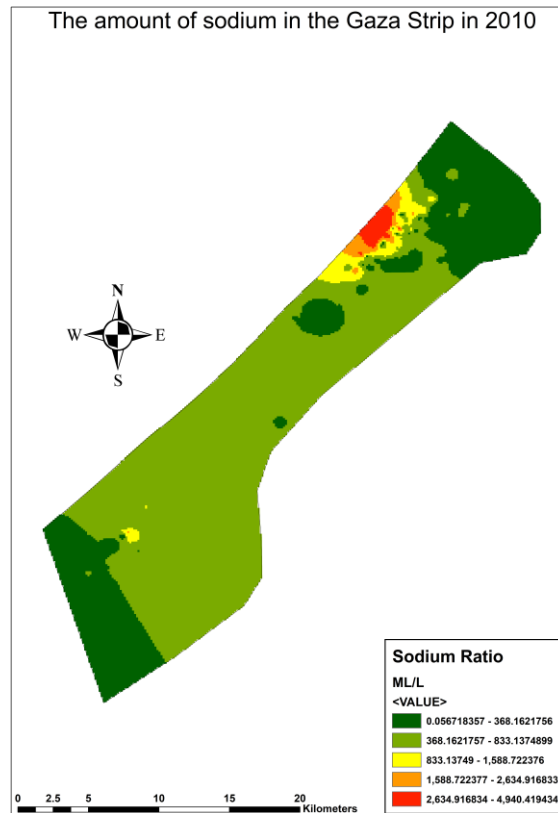


Figure 4.32 The Sodium rate in the Gaza Strip in 2010



Figure 4.33 The Sodium rate in the Gaza Strip in 2011

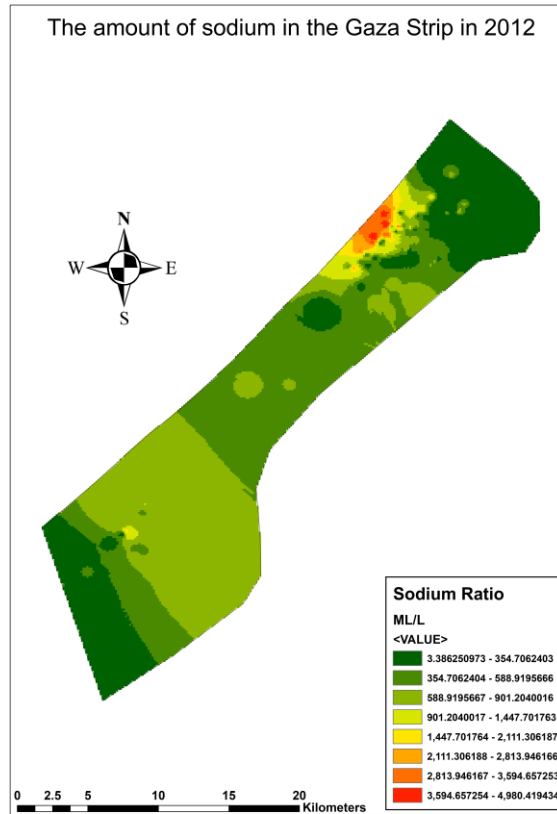


Figure 4.34 The Sodium rate in the Gaza Strip in 2012

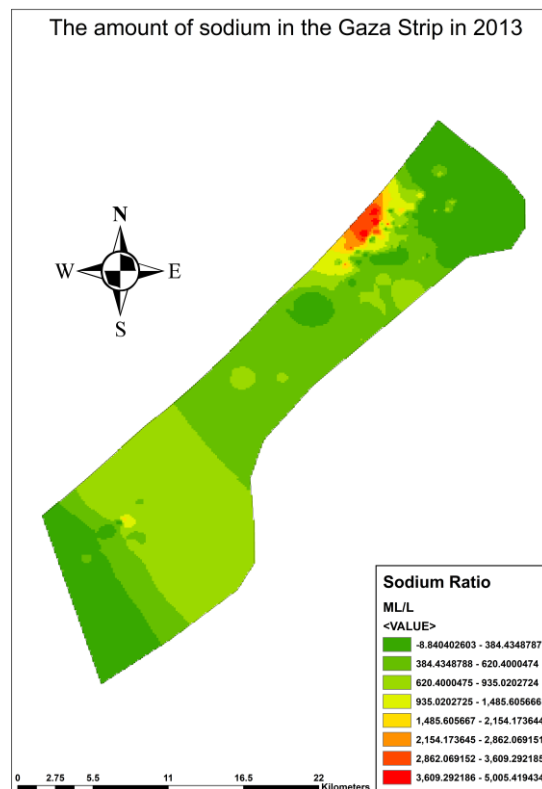


Figure 4.35 The Sodium rate in the Gaza Strip in 2013

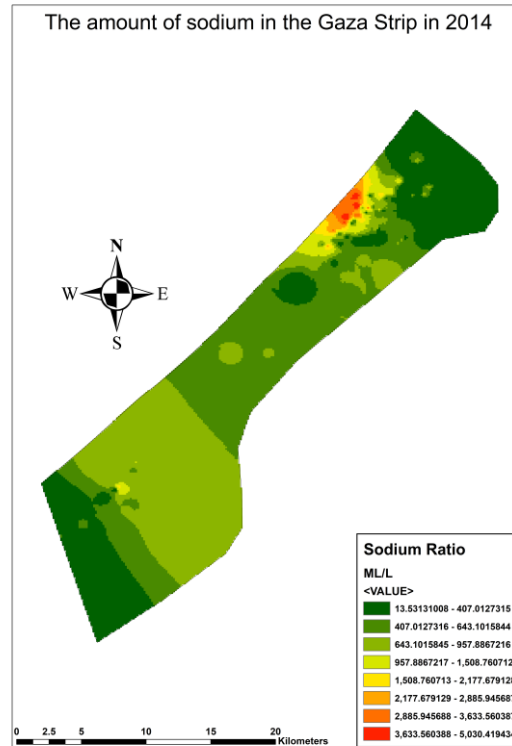


Figure 4.36 The Sodium rate in the Gaza Strip in 2014

Evaluation of the sodium element for the governorates of the Gaza Strip 2015

The average pollution with sodium element for 2015 was 500 mg/liter and a maximum of 2000 mg/l, and with reference to the standards set by the World Health Organization for nitrates is 200 mg/l, meaning that the level of pollution exceeded international standards almost three times, Figure 4.37. According to the 2015 Water Authority data, drinking water wells were monitored in the governorates of the Gaza Strip, and wells were extracted that are subject to international standards for the element sodium 200 mg/l at the governorate level, where the 38 wells of the North Governorate were monitored, and it was found that the majority of wells are subject to international standards for sodium, which is estimated at about 29 wells , for the wells of the Gaza Governorate, which numbered 64, it was found that only 7 wells are subject to the standards. As for the wells of Al-middle Governorate, which numbered 9, it was found that all of them exceeded the standards, and in Khan Yuns 15 wells were monitored, and it was found that only 5 wells are subject to the standards, and finally the wells of Rafah Governorate, the number of which is 18, it was found that only 3 wells are subject to international standards for sodium, and by collecting the usable wells, 44 wells out of 145 wells, meaning that the percentage does not exceed 30% as shown in Figure 4.38.

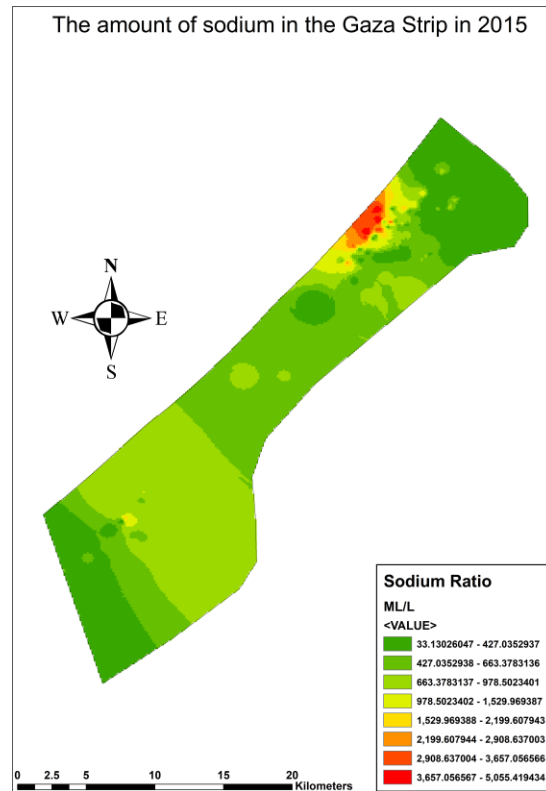


Figure 4.37 The Sodium rate in the Gaza Strip in 2015



Figure 4.38 The concentration of Sodium according to the standards of the World Health Organization (200 mg/L)

4.4.4 Potassium "K"

The following analyzes in figures 4.39 to 4.46 show the percentage of potassium in groundwater wells in the Gaza Strip over the previous years (2007,2014) show the degree of water pollution and its compliance with the standards of the World Health Organization, as it was found that the lowest percentage of water wells that comply with the standards of the World Health Organization for potassium element was estimated about 20% in 2015, and the highest percentage of water wells that comply with the standards of the World Health Organization with potassium is estimated at about 97% in 2007.

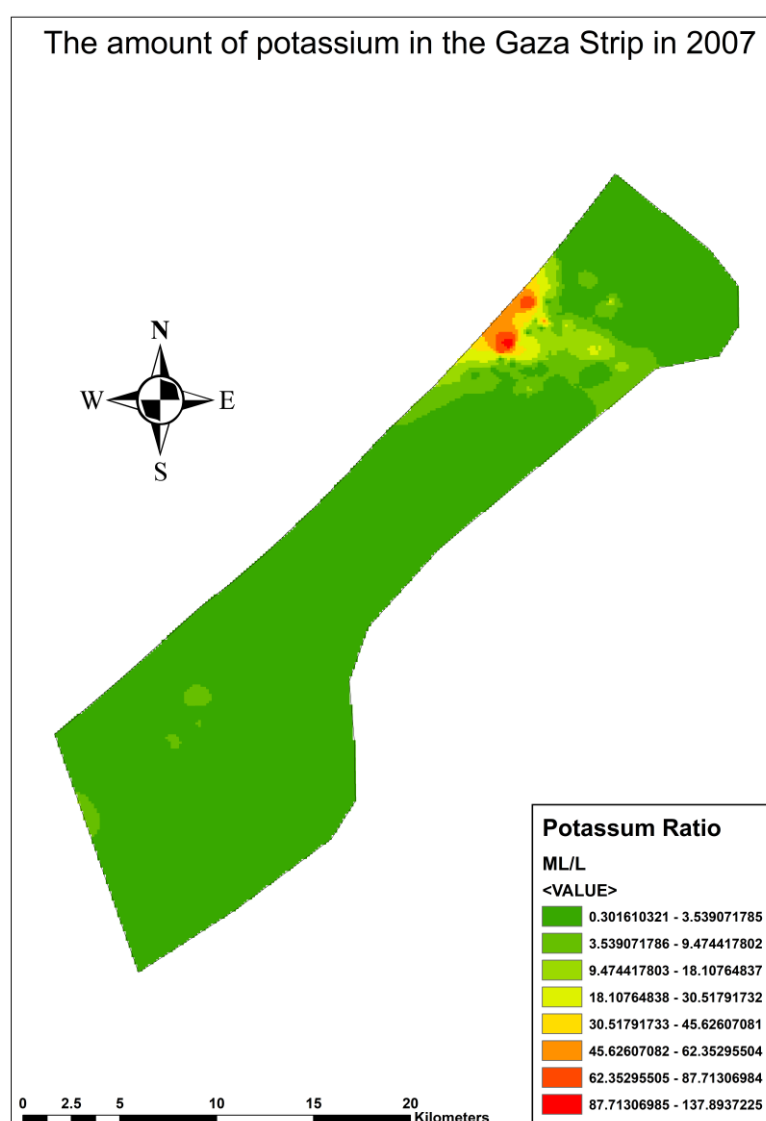


Figure 4.39 The Potassium rate in the Gaza Strip in 2007

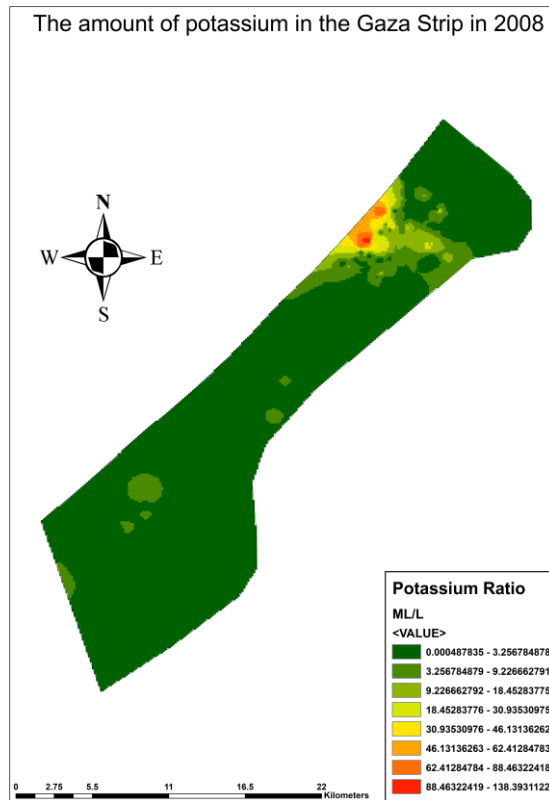


Figure 4.40 The Potassium rate in the Gaza Strip in 2008

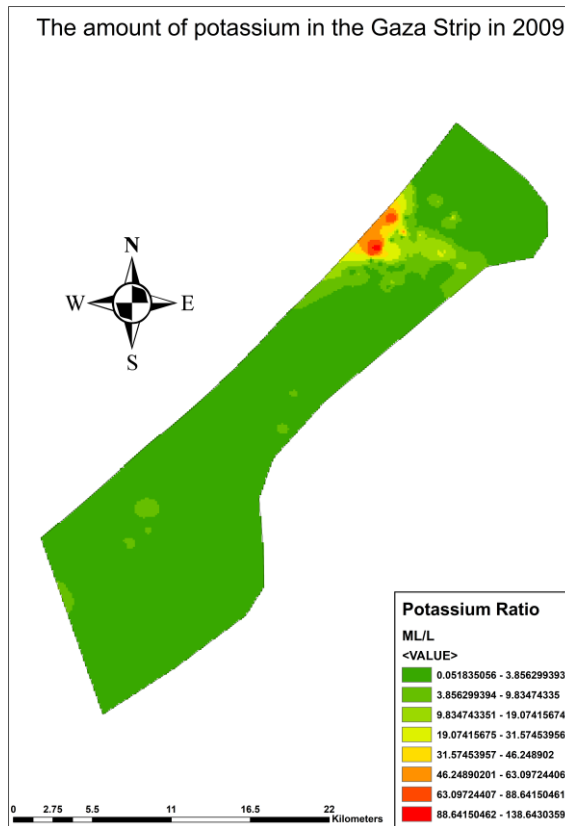


Figure 4.41 The Potassium rate in the Gaza Strip in 2009

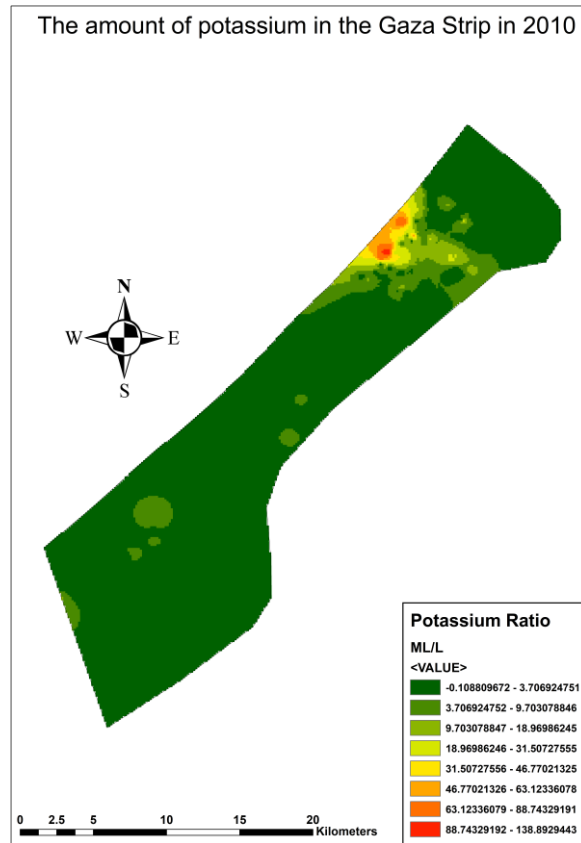


Figure 4.42 The Potassium rate in the Gaza Strip in 2010

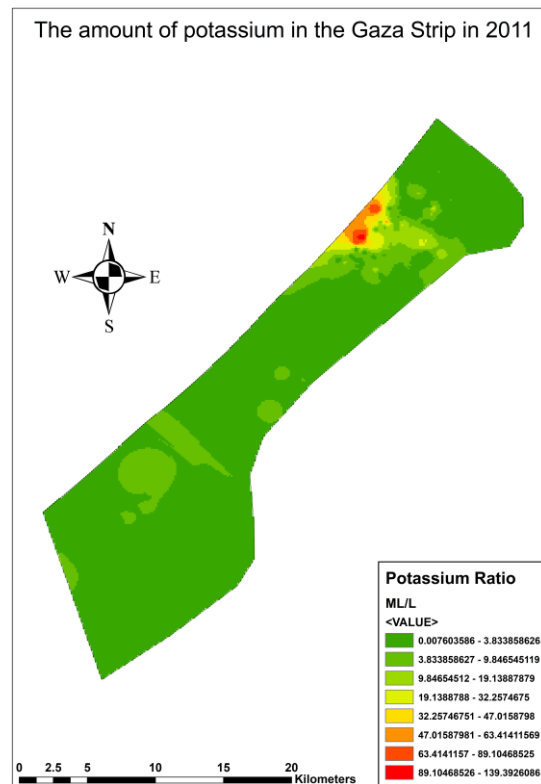


Figure 4.43 The Potassium rate in the Gaza Strip in 2011

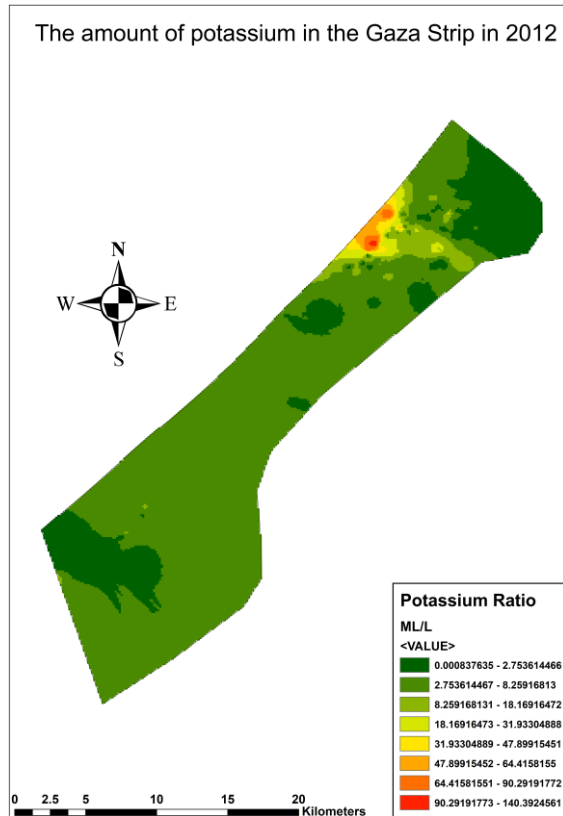


Figure 4.44 The Potassium rate in the Gaza Strip in 2012

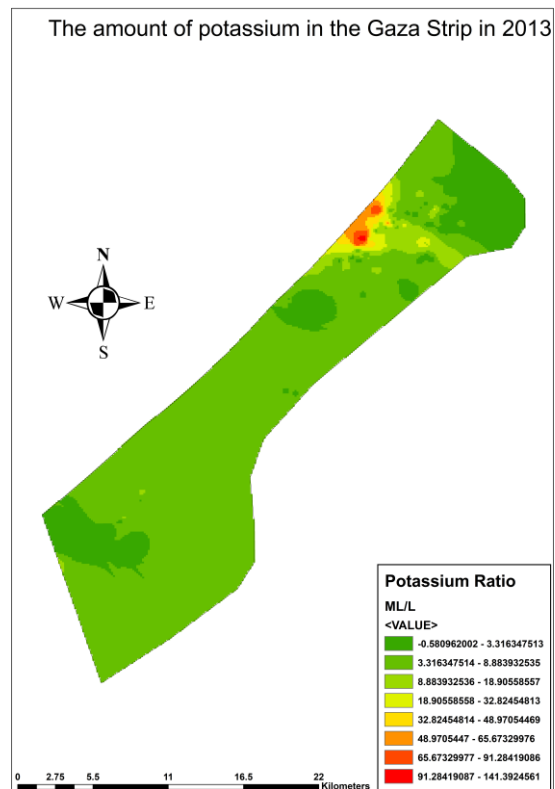


Figure 4.45 The Potassium rate in the Gaza Strip in 2013

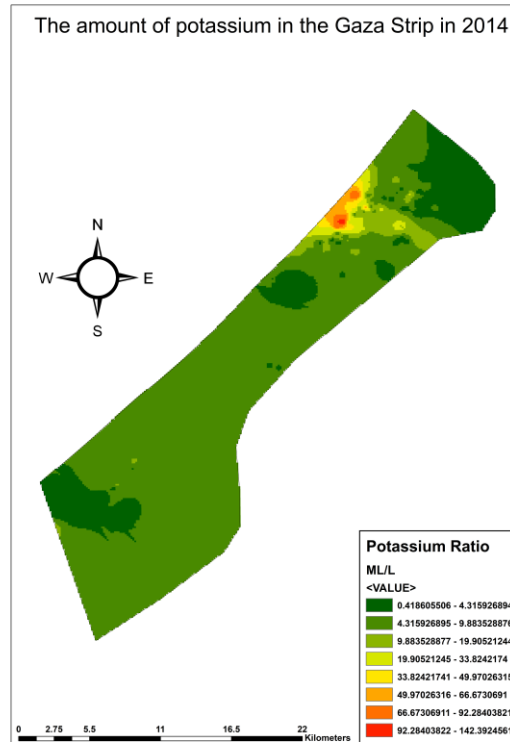


Figure 4.46 The Potassium rate in the Gaza Strip in 2014

Potassium assessment for the Gaza Strip governorates 2015.

Contamination with potassium is considered one of the manifestations of chemical pollution, where the average concentration of potassium reached 11 mg/l and a maximum of 144 mg/l, and with reference to the standards set by the World Health Organization for potassium is 12 mg/l, meaning that the level of contamination exceeded international standards by a percentage almost non-existent Figure 4.47. Based on the data of the Water Authority for the year 2015, the wells of the governorates of the Gaza Strip were monitored and the number of wells that are subject to international standards for potassium was extracted at the governorate level. The drinking water wells were monitored in the North Governorate, which numbered 38 wells, It was found that only 2 of the wells were not subject to the international standards for potassium, For the drinking water wells in the Gaza Governorate, totaling 64 wells, it was found that 21 wells were not subject to the international health standards for potassium, and the drinking water wells in the middle Governorate , totaling 9, were found to be subject to according to international standards for potassium, in Khan Yuns 15 wells were monitored, it was found that only one well is not subject to international standards for potassium, and finally the wells of Rafah governorate whose number of wells is 18, it was found that

4 wells are not subject to international standards for potassium , we conclude from this that the number of wells unfit for human use for potassium is 29 out of 145 wells, meaning that the percentage did not exceed 20% and this percentage is considered good compared to the ratios of the previous elements Figure 4.48.

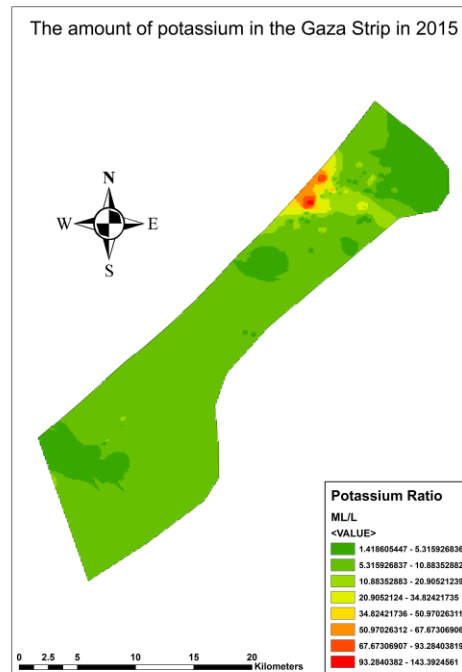


Figure 4.47 The Potassium rate in the Gaza Strip in 2015



Figure 4.48 The concentration of Potassium according to the standards of the World Health Organization (12 mg/L)

4.4.5 Magnesium "Mg"

The following analyzes in figures 4.49 to 4.56 show the percentage of magnesium in the groundwater wells of the Gaza Strip over the years (2007, 2014), the degree of water pollution, and its compatibility with the standards of the World Health Organization, as it was found that the lowest percentage of water wells that comply with the standards of the World Health Organization for potassium element was estimated about 18% in 2015, and the highest percentage that complies with the standards of the World Health Organization with magnesium is estimated at about 95% in 2007.

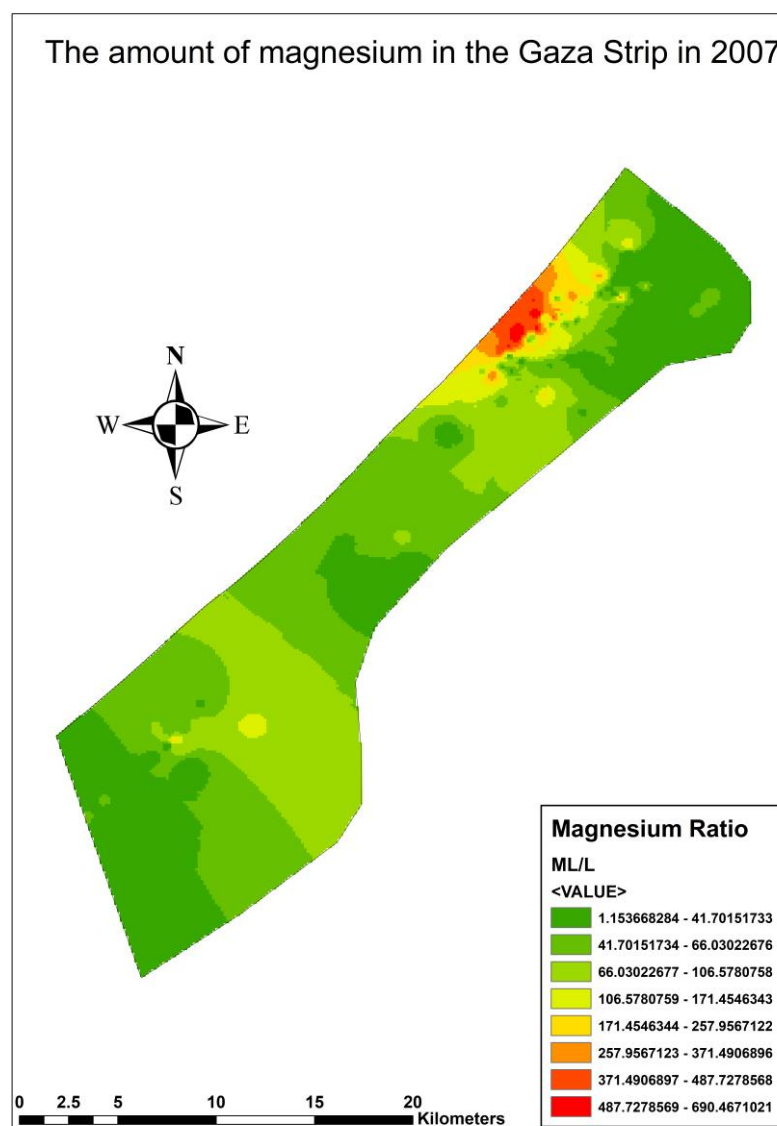


Figure 4.49 The magnesium rate in the Gaza Strip in 2007

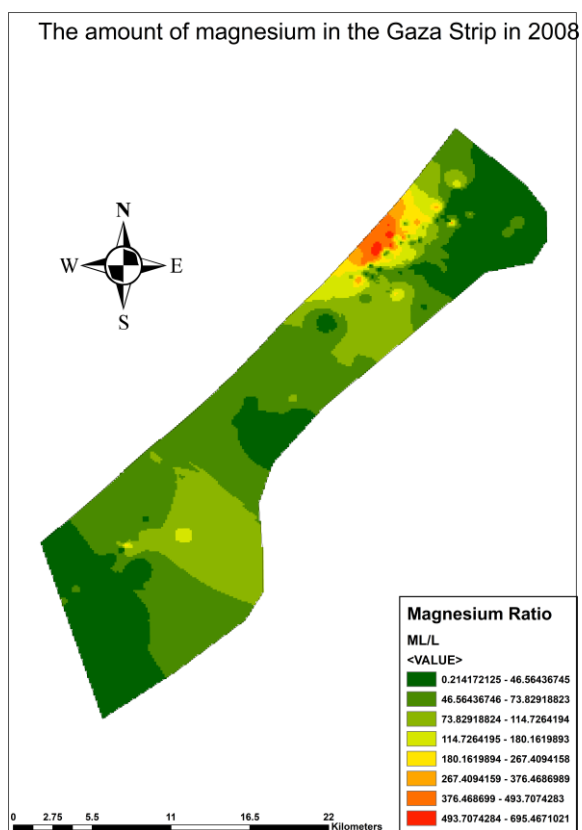


Figure 4.50 The magnesium rate in the Gaza Strip in 2008

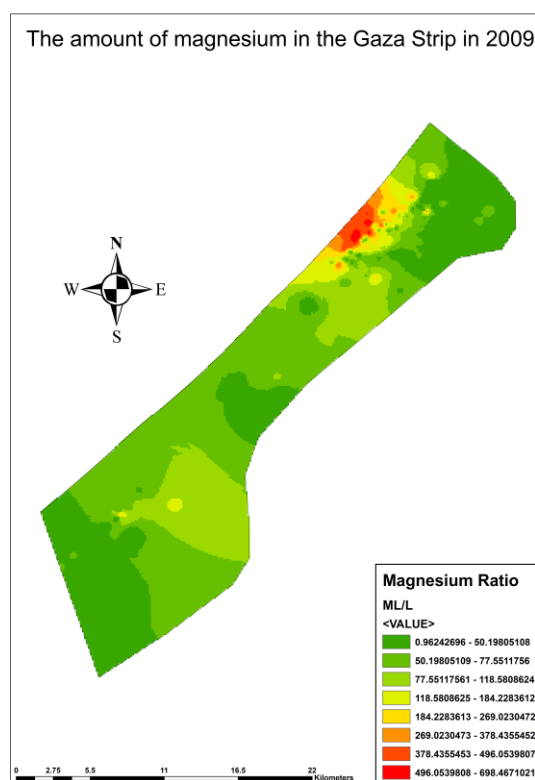


Figure 4.51 The magnesium rate in the Gaza Strip in 2009

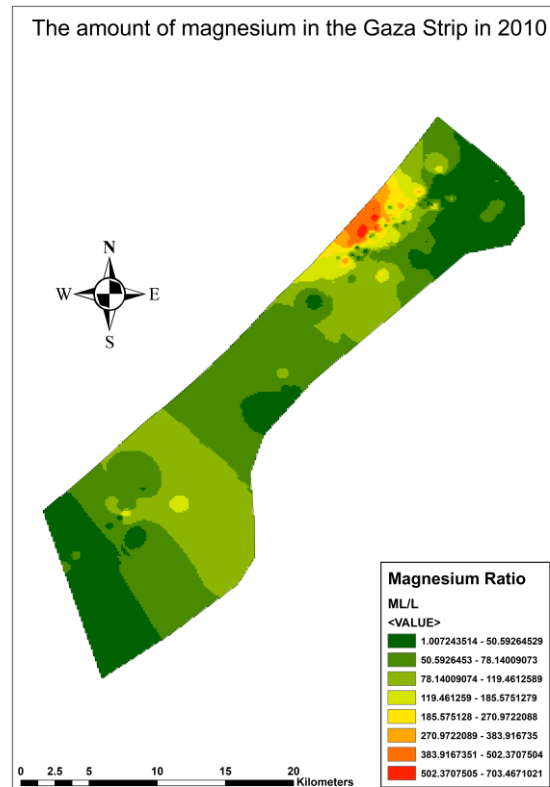


Figure 4.52 The magnesium rate in the Gaza Strip in 2010

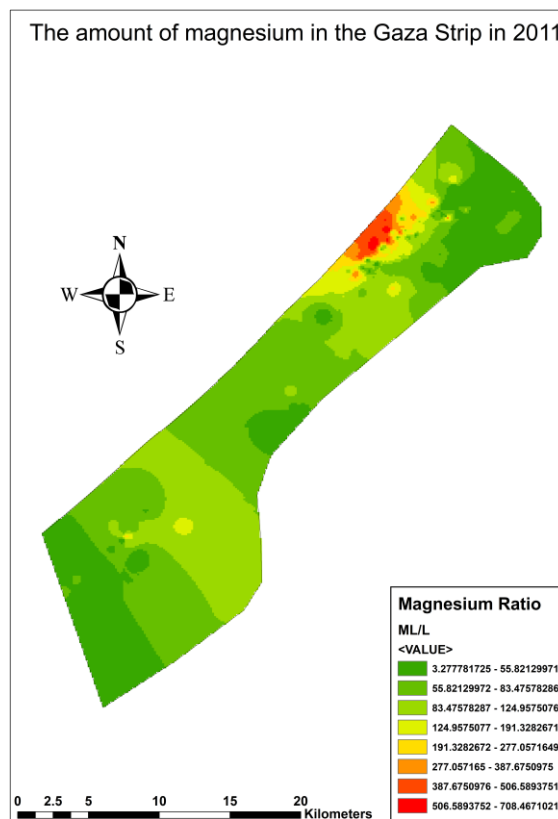


Figure 4.53 The magnesium rate in the Gaza Strip in 2011

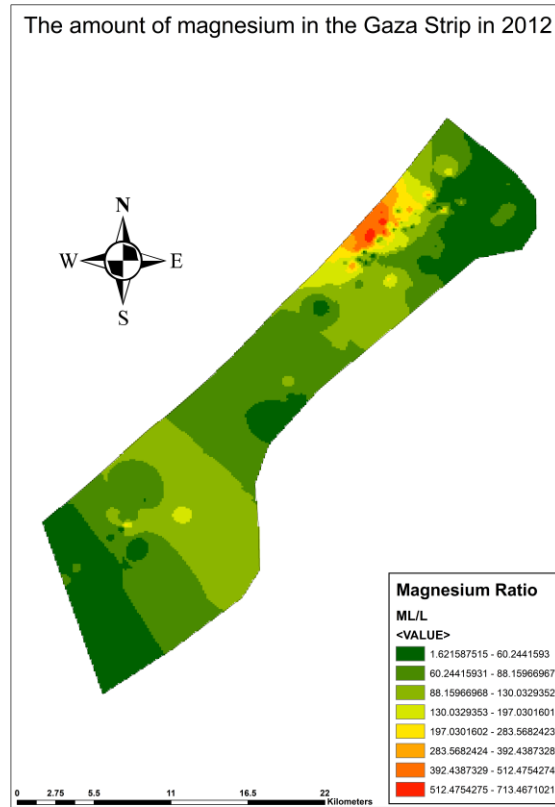


Figure 4.54 The magnesium rate in the Gaza Strip in 2012

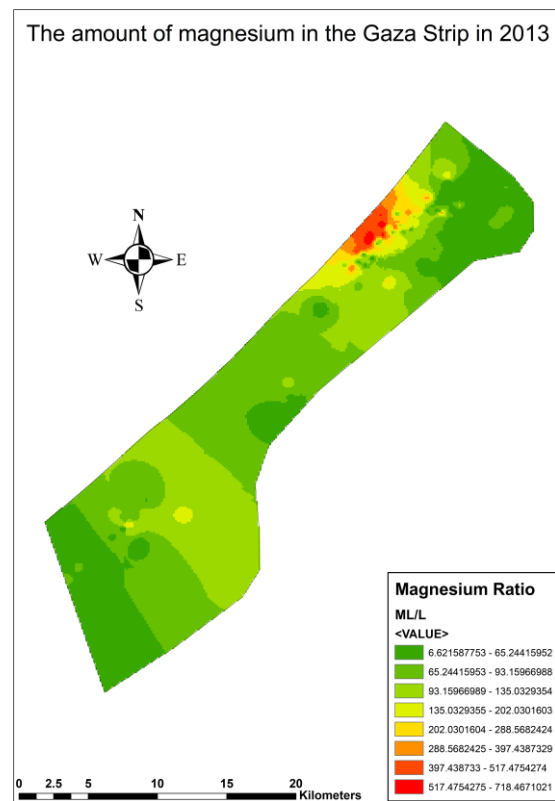


Figure 4.55 The magnesium rate in the Gaza Strip in 2013

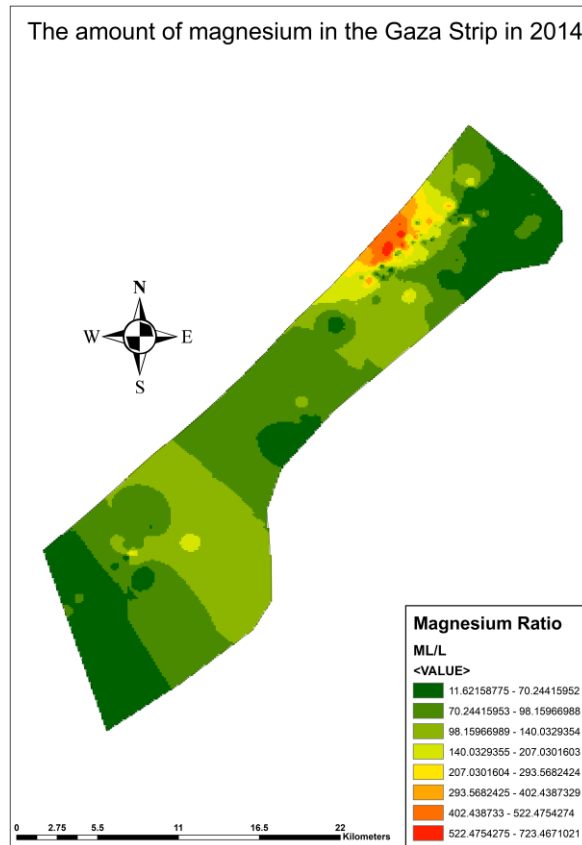


Figure 4.56 The magnesium rate in the Gaza Strip in 2014

Magnesium assessment for the Gaza Strip governorates in 2015.

The average concentration of magnesium to 130 mg/L and a maximum of 761 mg/L, and with the standards identified by the World Health Organization (WHO) are 150 mg/L, that is, the level of pollution has exceeded international standards for Gaza form 4.57 and on the data of the Ministry of Water 2015, drinking water wells were monitored in the governorates of the Gaza Strip and the extraction of well-standing wells for the magnesium element, where the North Governorate of 38 wells were monitored, found that only two wells are not subject to international standards for the magnesium element The Survey and Survey of Khan Yuns Governorate Wells, found that only one well not subject to the standards and finally the wells of Rafah province holders 18, found that only 3 wells are not subject to international standards for the Magnesium element. The results of the evaluation show that the number of non-human well-use wells for the magnesium component 27 wells out of 145wells, is not exceeding 18% as shown in figure 4.58.

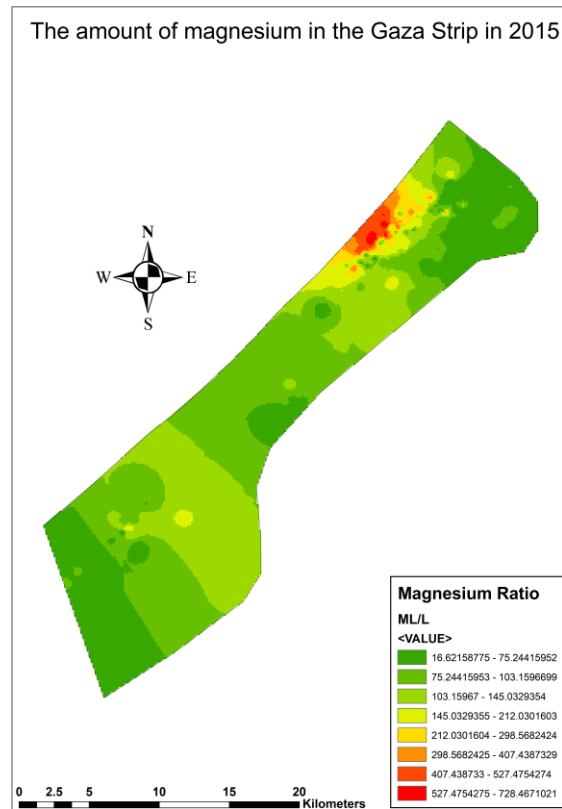


Figure 4.57 The magnesium rate in the Gaza Strip in 2015

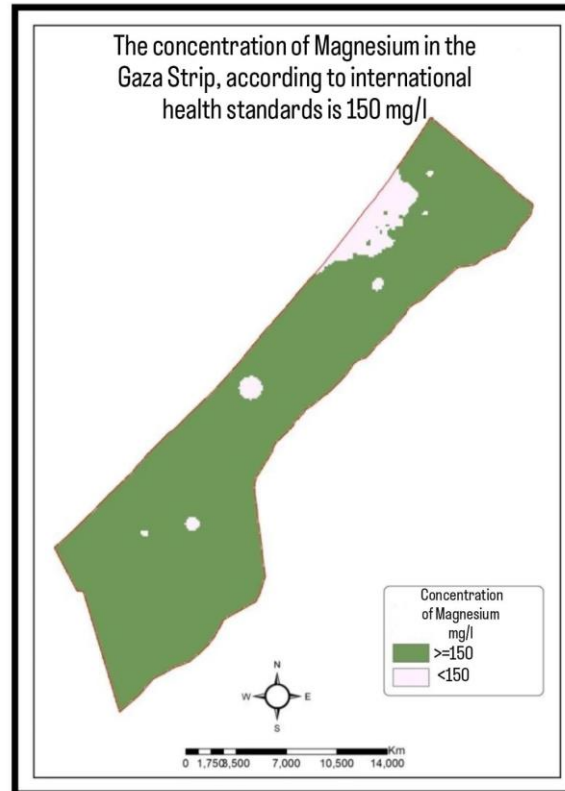


Figure 4.58 The concentration of magnesium according to the standards of the World Health Organization (150 mg/L)

4.4.6 Calcium "Ca"

The following analyzes in figures 4.59 to 4.66 show the percentage of calcium element in groundwater wells in the Gaza Strip over the years (2007, 2015) show the degree of water pollution and its compliance with the standards of the World Health Organization, as it was found that the lowest percentage of water wells that comply with the standards of the World Health Organization for potassium element was estimated about 85% in 2015, and the highest percentage of well water that complies with the standards of the World Health Organization with calcium element is estimated at about 89.7% in 2010.

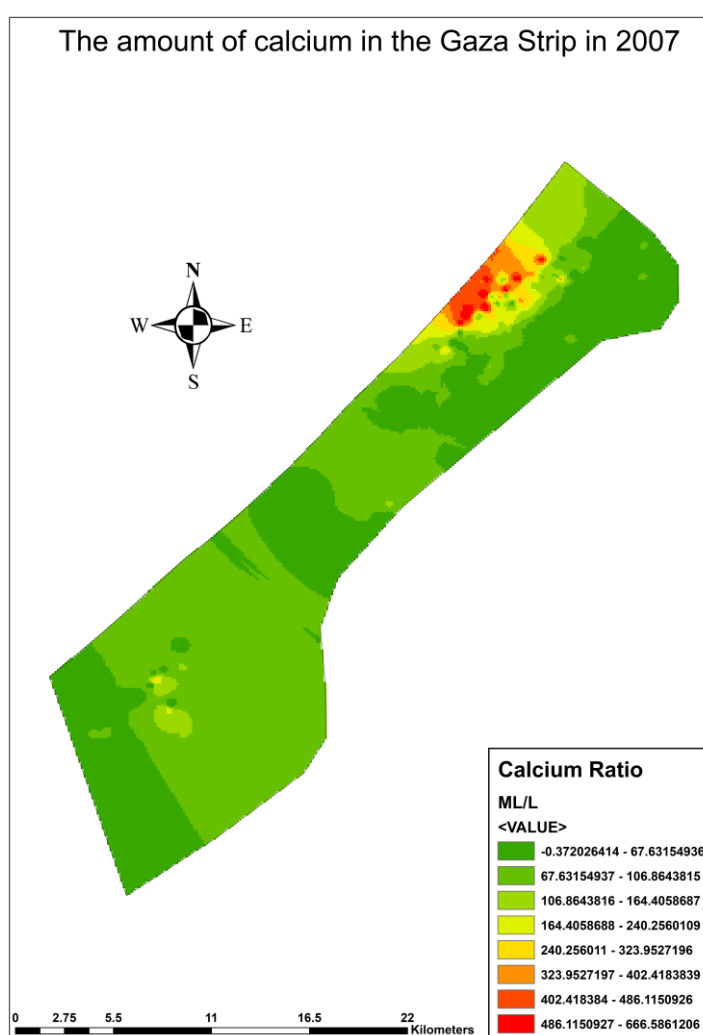


Figure 4.59 The Calcium rate in the Gaza Strip in 2007

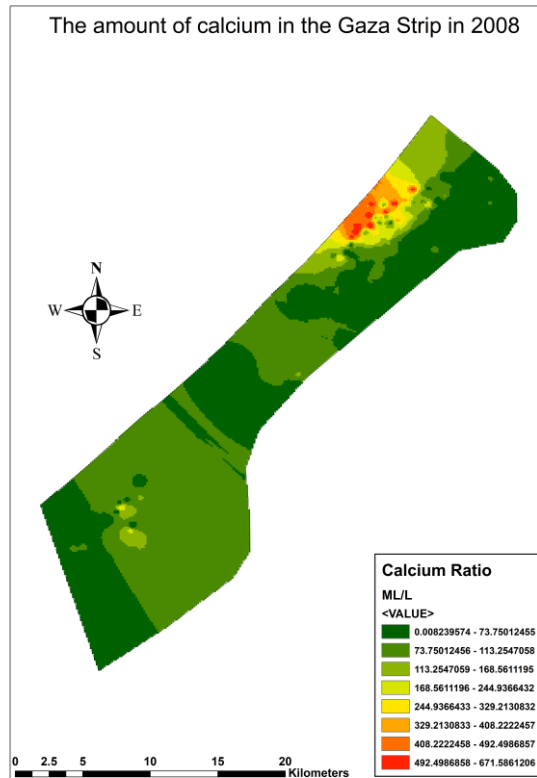


Figure 4.60 The Calcium rate in the Gaza Strip in 2008

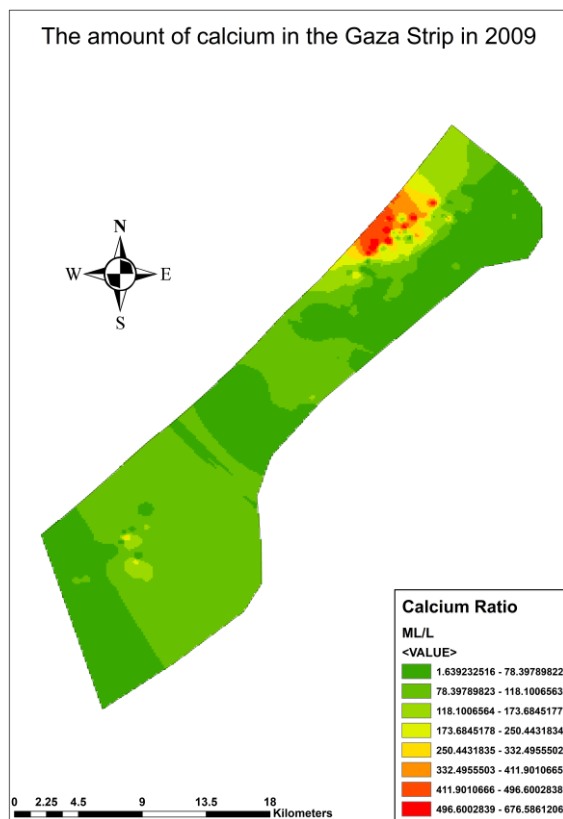


Figure 4.61 The Calcium rate in the Gaza Strip in 2009

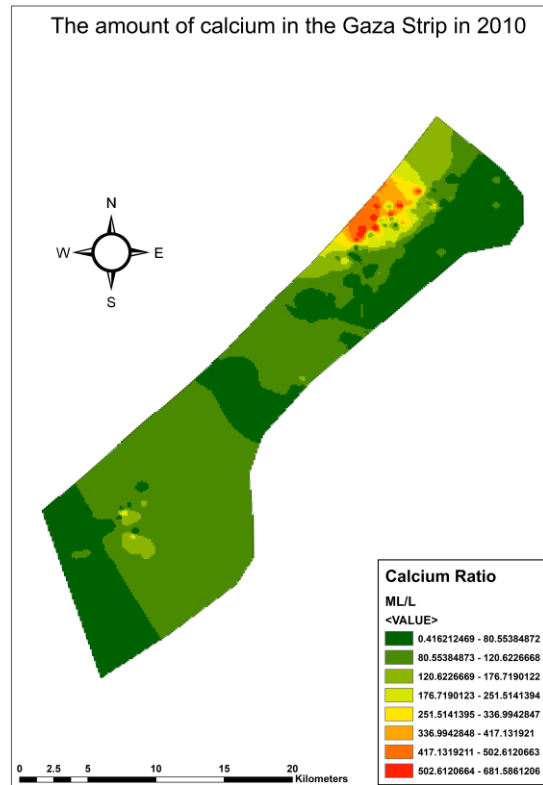


Figure 4.62 The Calcium rate in the Gaza Strip in 2010

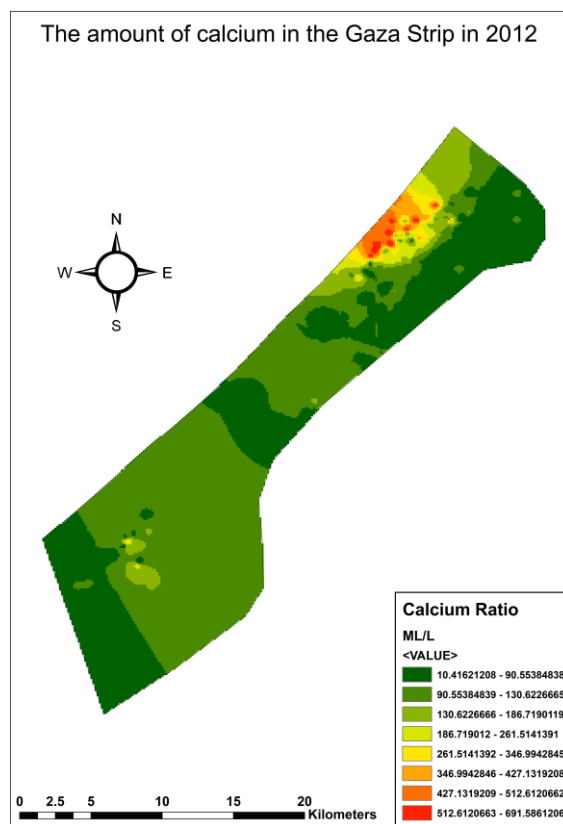


Figure 4.63 The Calcium rate in the Gaza Strip in 2011

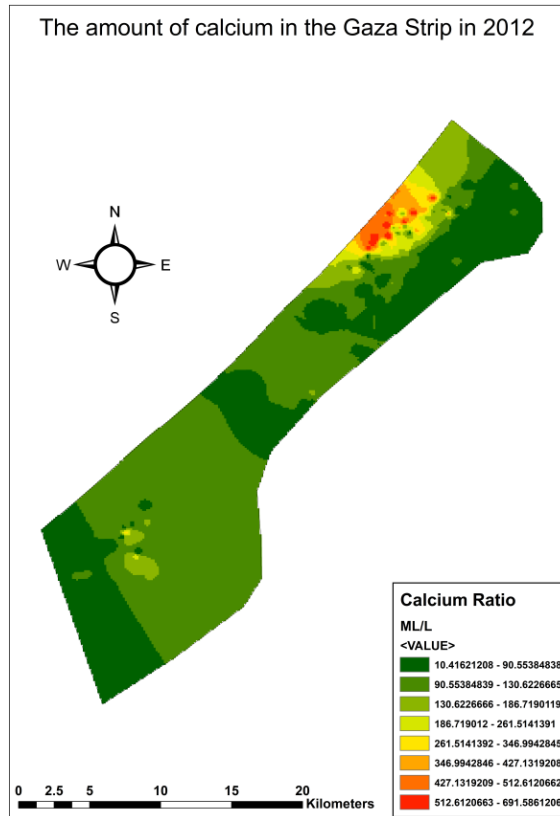


Figure 4.64 The Calcium rate in the Gaza Strip in 2012

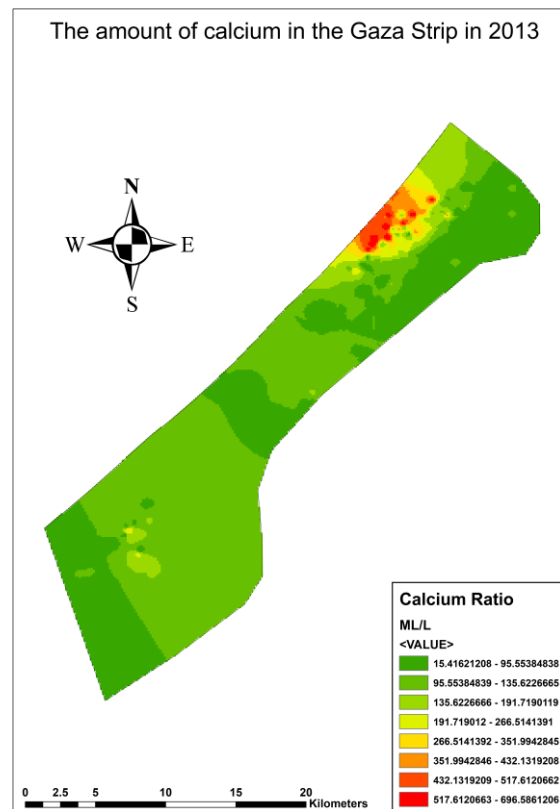


Figure 4.65 The Calcium rate in the Gaza Strip in 2013

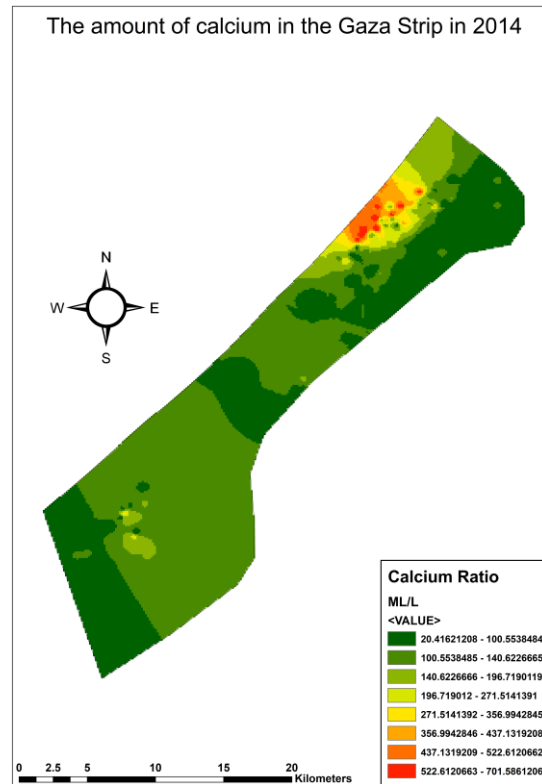


Figure 4.66 The Calcium rate in the Gaza Strip in 2014

Calcium assessment for Gaza Strip governorates2015.

Calcium pollution is one of the manifestations of chemical pollution, where the average concentration of calcium reached 158 mg/l and a maximum of 700 mg/l, and by reference to the standards set by the World Health Organization for calcium 200 mg/l, meaning that the level of contamination exceeded international standards Figure 4.67, Based on the data of the Water Authority for 2015, drinking water wells were monitored in the governorates of the Gaza Strip, and wells were extracted that are subject to international standards for calcium at the governorate level Calcium, as for the wells of the Gaza Governorate, which numbered 64, it was found that only 17wells were not subject to the standards, as well as the wells of the middle Governorate, which obtained 9 wells, and Khan Yuns Governorate 15 wells, it was found that all of them are subject to the standards 18, it was found that only 2 wells do not meet the international standards for calcium The previous results show that the number of wells suitable for human use relative to calcium is 123 out of 145 wells, meaning that the percentage of wells unfit for human use does not exceed 15%, as shown in Figure 4.68.

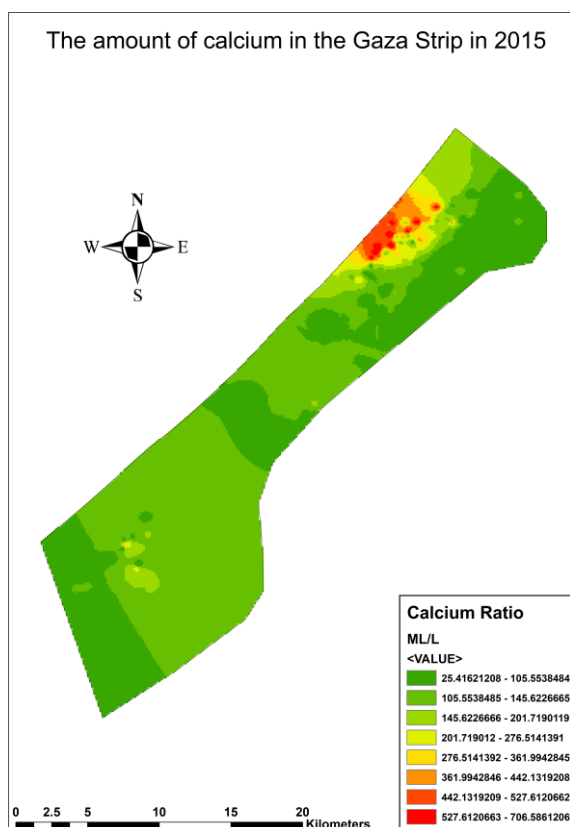


Figure 4.67 The Calcium rate in the Gaza Strip in 2015

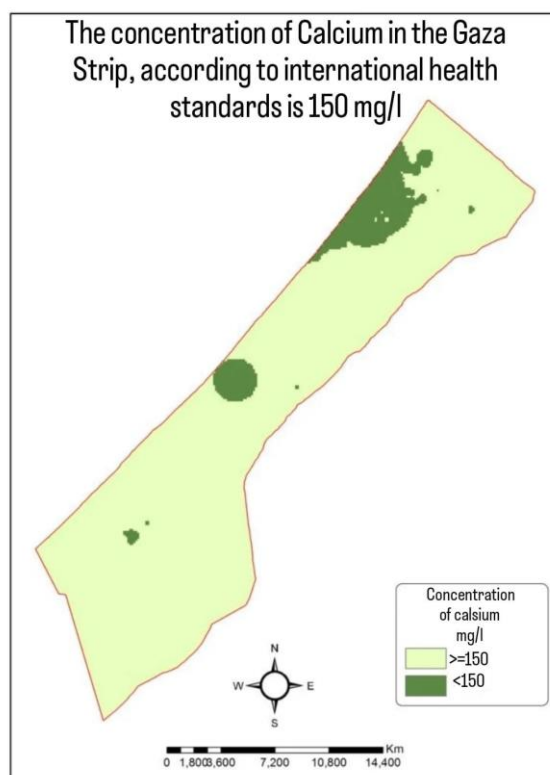


Figure 4.68 The concentration of Calcium according to the standards of the World Health Organization (150 mg/L)

4.4.7 Hardness.

The following analyzes in figures 4.69 to 4.76 show the percentage of the water hardness component in groundwater wells in the Gaza Strip over the years (2007, 2015) show the degree of water pollution and its compliance with the standards of the World Health Organization, as it was found that the lowest percentage of water wells that comply with the standards of the World Health Organization for hardness element was estimated about at 37.2% in the year 2015, and the highest percentage of well water that complies with the standards of the World Health Organization with the water hardness component was estimated at about 97% in the year 2007.

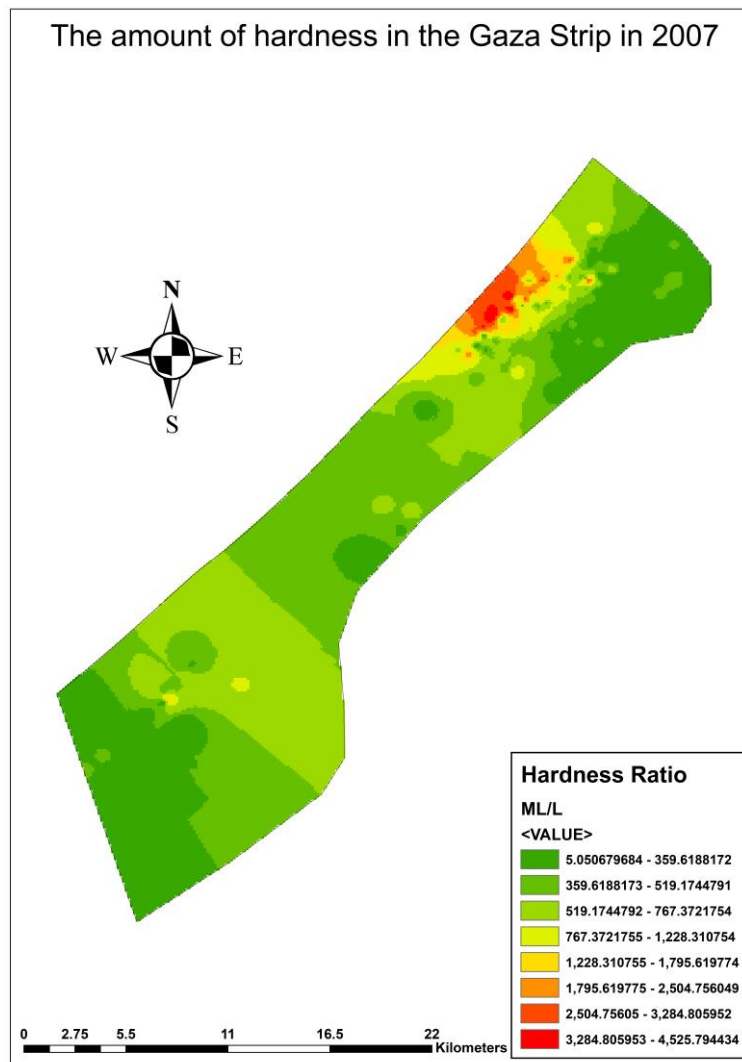


Figure 4.69 The hardness rate in the Gaza Strip in 2007

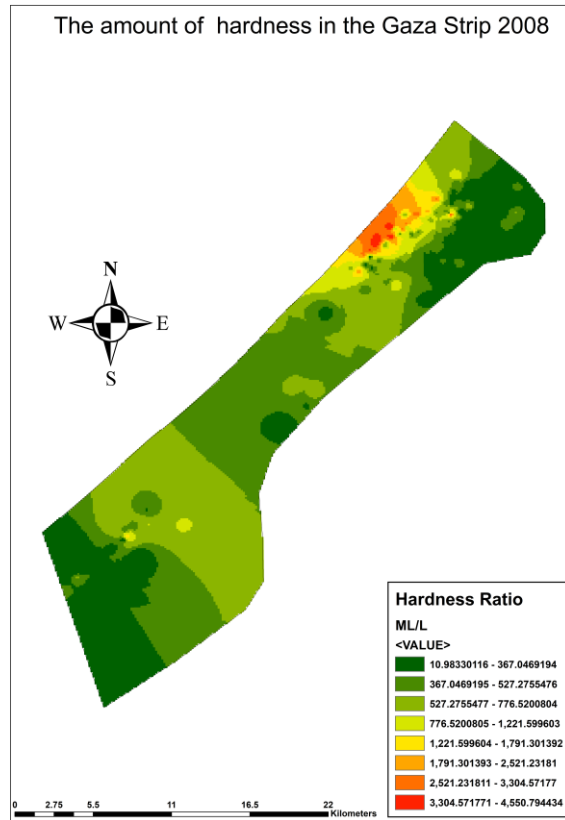


Figure 4.70 The hardness rate in the Gaza Strip in 2008

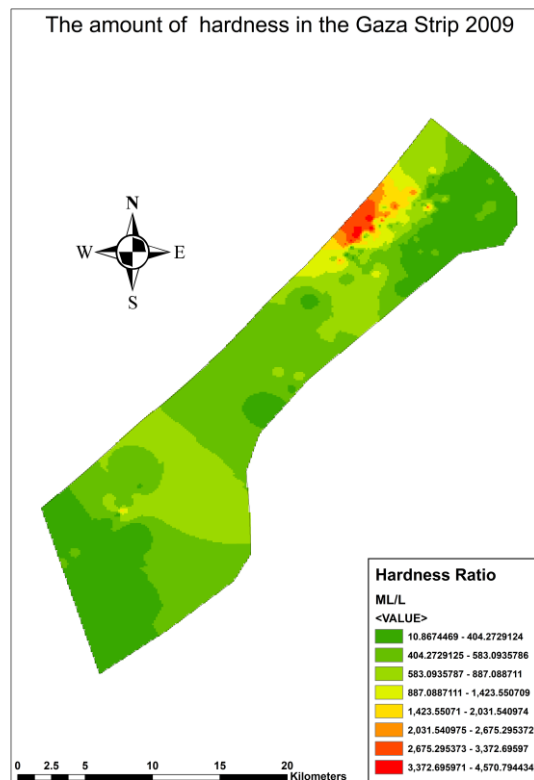


Figure 4.71 The hardness rate in the Gaza Strip in 2009

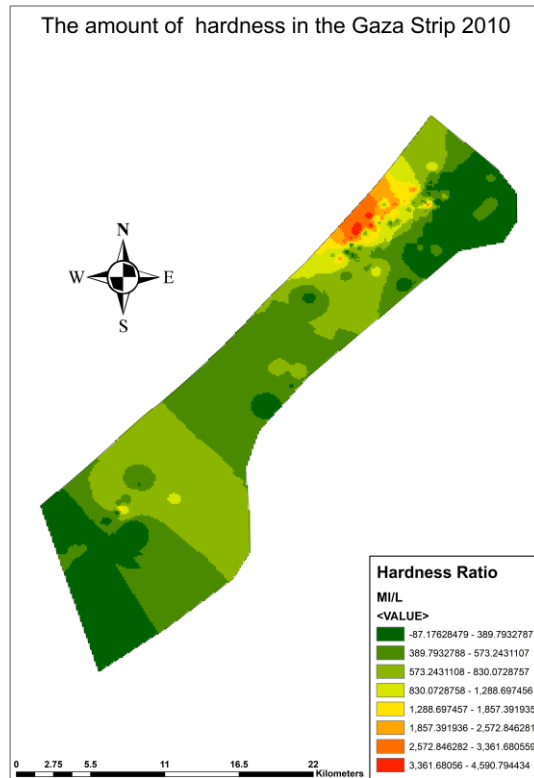


Figure 4.72 The hardness rate in the Gaza Strip in 2010

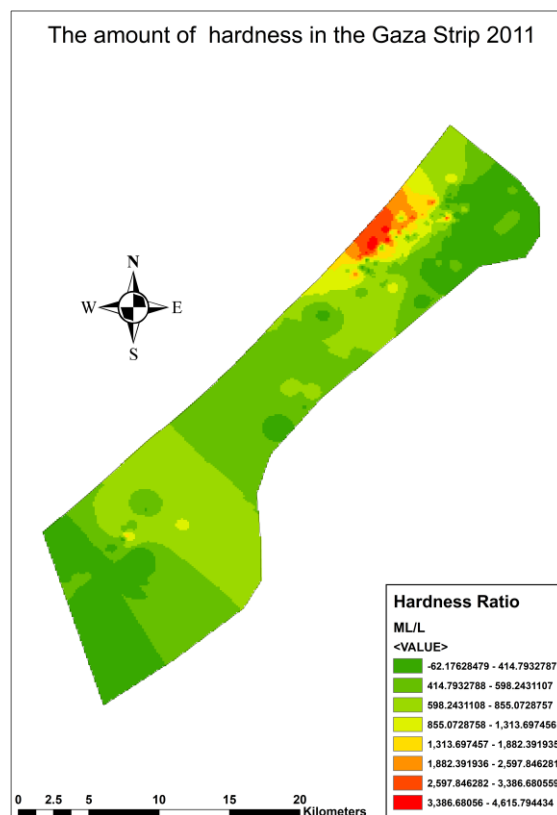


Figure 4.73 The hardness rate in the Gaza Strip in 2011

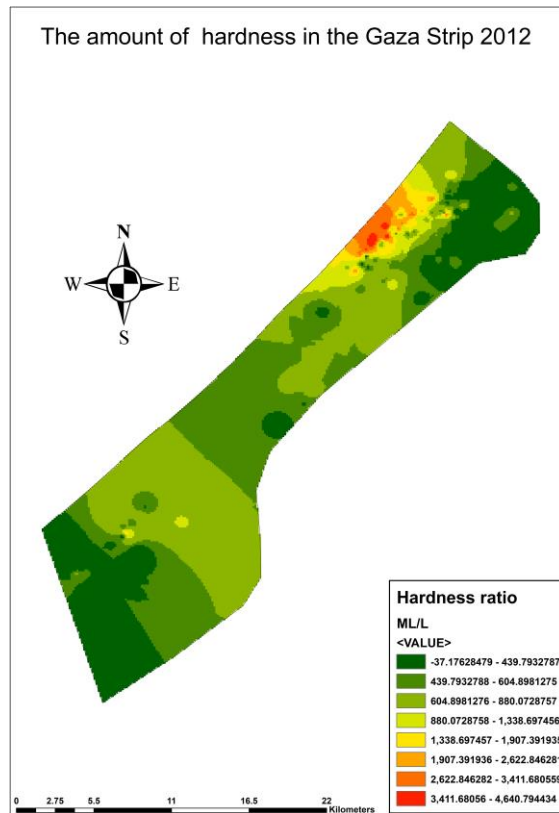


Figure 4.74 The hardness rate in the Gaza Strip in 2012

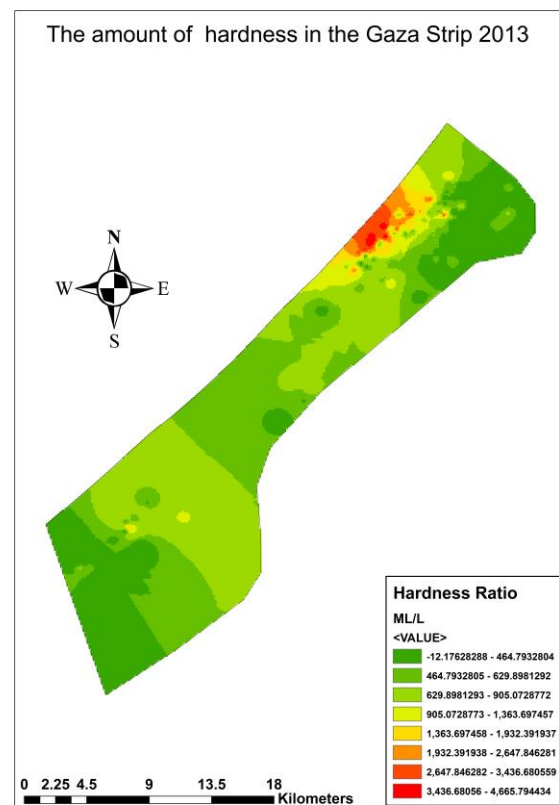


Figure 4.75 The hardness rate in the Gaza Strip in 2013

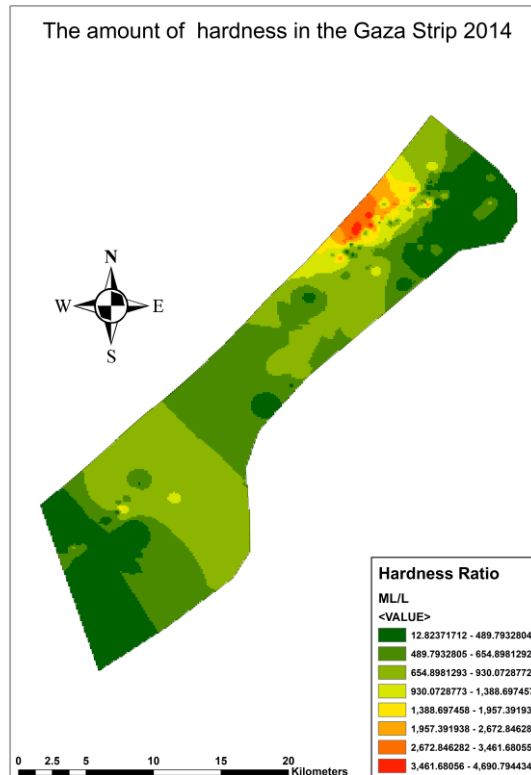


Figure 4.76 The hardness rate in the Gaza Strip in 2014

Assessment of water hardness for the Gaza Strip governorates 2015.

Water hardness pollution is one of the manifestations of chemical pollution, where the average concentration of water hardness reached 900 mg/l and a maximum of 4000 mg/l, and with reference to the criteria set by the World Health Organization for the element of water hardness is 600 mg/l, meaning that the level of pollution exceeded the standards international level almost quadrupled, Figure 4.77. Based on the 2015 Water Authority data, drinking water wells were monitored in the governorates of the Gaza Strip and the extraction of wells that are subject to international standards for the water hardness component at the governorate level. The North Governorate's 38 wells were monitored, and it was found that 8 wells are not subject to international standards As for the wells of the Gaza Governorate, which numbered 64, it was found that 23 wells were not subject to the standards, and the same was true for the wells of the central Governorate, which numbered 9, and it was found that 4 wells were not subject to the standards, and for Khan Yuns Governorate, 15 wells were observed, and it was found that 10 wells were not subject to the standards According to the standards, and finally the wells of Rafah

Governorate, the total number of which is 19, it was found that only 9 wells are not subject to international standards for the element of water hardness. The results show that the number of wells unfit for human use for the water hardness element in 2015 was 54 out of 145 wells, with a percentage of 37.2% as shown in Figure 4.78.

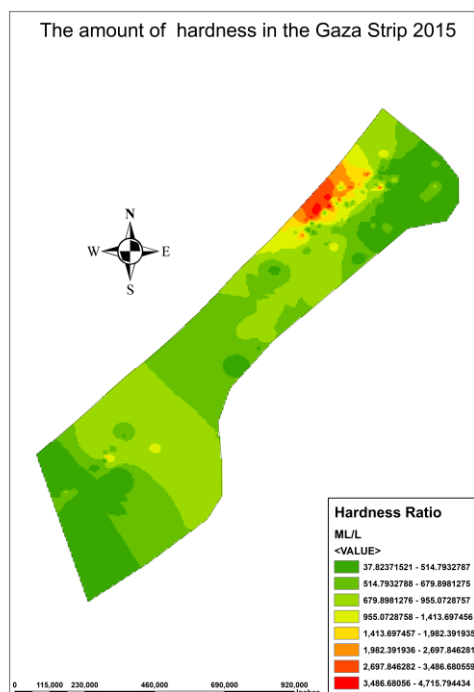


Figure 4.77 The hardness rate in the Gaza Strip in 2015



Figure 4.78 The concentration of hardness according to the standards of the World Health Organization (600 mg/L)

4.4.8 Total Dissolved solids "TDs".

The following analyzes in figures 4.79 to 4.86 show the percentage of the dissolved solids component in the groundwater wells in the Gaza Strip over the years (2007,2015) show the degree of water pollution and its compatibility with the standards of the World Health Organization, as it was found that the lowest percentage of water wells that comply with the standards of the World Health Organization for Dissolved solids element was estimated about at 17.2% in the year 2015, and the highest percentage of water wells that comply with the standards of the World Health Organization with the element of dissolved solids was estimated at about 47.5% in 2007.



Figure 4.79 The Dissolved solids "TDs" rate in the Gaza Strip in 2007

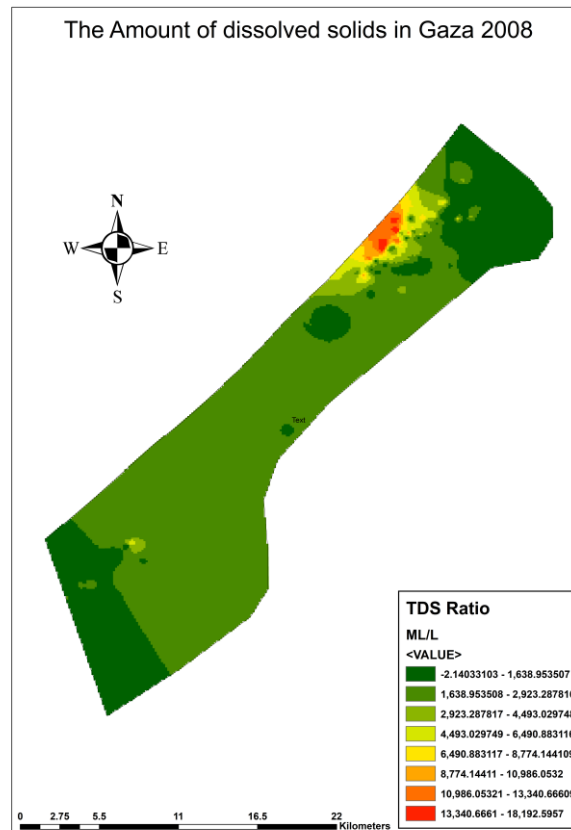


Figure 4.80 The Dissolved solids "TDs" rate in the Gaza Strip in 2008



Figure 4.81 The Dissolved solids "TDs" rate in the Gaza Strip in 2009

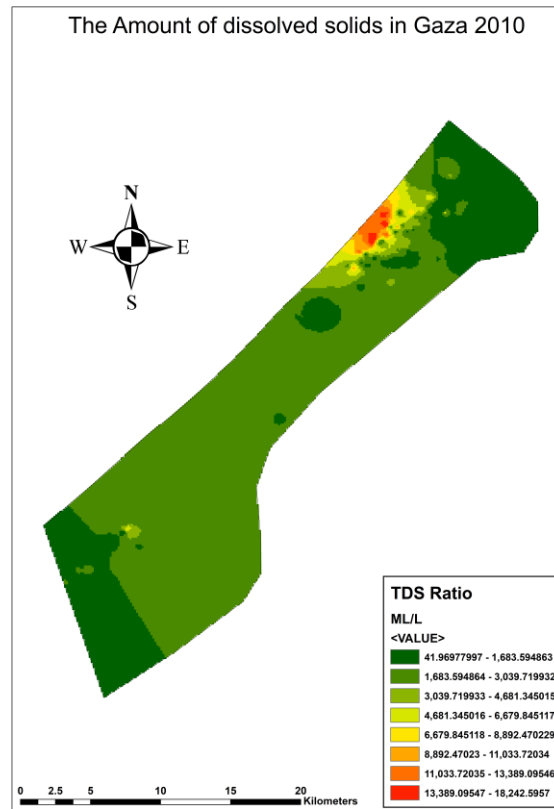


Figure 4.82 The Dissolved solids "TDs" rate in the Gaza Strip in 2010



Figure 4.83 The Dissolved solids "TDs" rate in the Gaza Strip in 2011

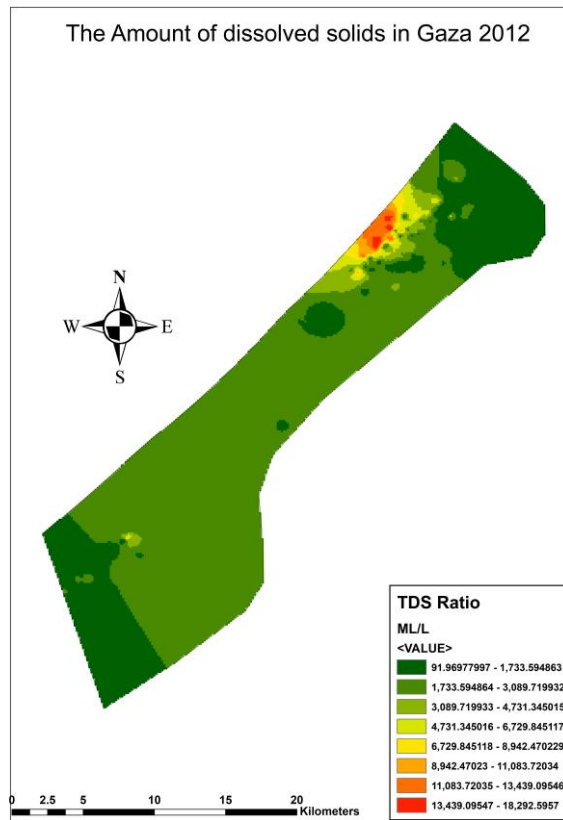


Figure 4.84 The Dissolved solids "TDs" rate in the Gaza Strip in 2012

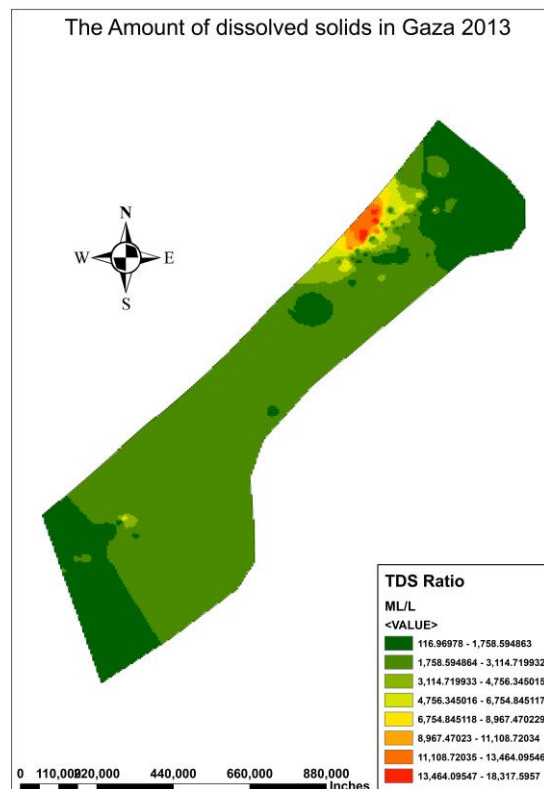


Figure 4.85 The Dissolved solids "TDs" rate in the Gaza Strip in 2013

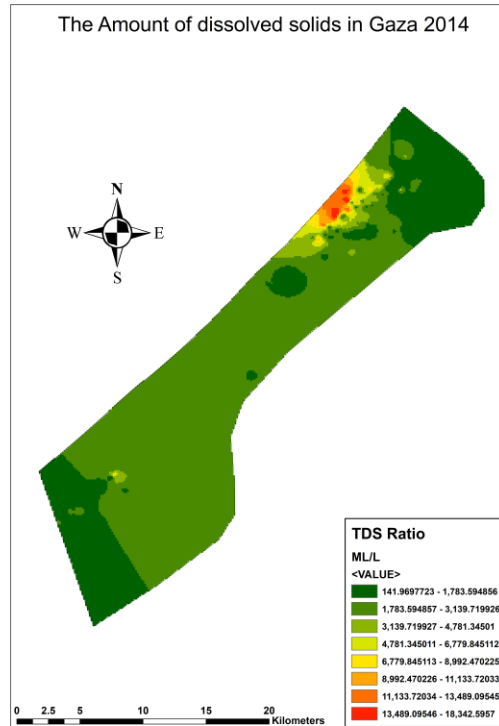


Figure 4.86 The Dissolved solids "TDs" rate in the Gaza Strip in 2014

Assessment of Dissolved solids for the governorates of the Gaza Strip 2015.

Pollution by dissolved solids is one of the manifestations of chemical pollution, where the average concentration of dissolved solids reached 2900 mg/l and a maximum of 19,000 mg/l, and with reference to the standards set by the World Health Organization for dissolved solids is 1000 mg/l, that is, the level of pollution Exceeding international standards almost three times, Figure 4.87. Based on the data of the Ministry of Water for the year 2015, drinking water wells were monitored in the governorates of the Gaza Strip and the extraction of wells that are subject to international standards for the element of dissolved solids at the governorate level and the wells of the Gaza Governorate, totaling 64 wells, it was found that only 4 wells are subject to the standards, and for the wells of the Central Governorate, which numbered 9, it was found that all of them are not subject to the standards, and for the wells of Khan Yuns, 15 wells were monitored, and it was found that only 4 wells comply with international standards for materials Dissolved solids, and finally the wells of Rafah governorate whose number of wells is 18, it was found that only 3 wells are subject to international standards for the element of dissolved solids .The previous results show that the number of wells suitable for human use for the

component of dissolved solids in 2015, it was found that they do not exceed 25 out of 145 wells, with a rate of 17.2% as shown in Figure 4.88.



Figure 4.87 The Dissolved solids rate in the Gaza Strip in 2015

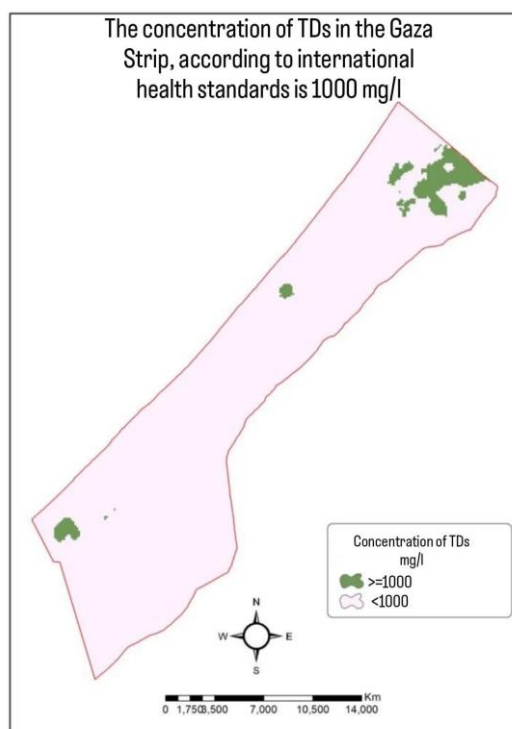


Figure 4.88 The concentration of Dissolved solids according to the standards of the World Health Organization (1000 mg/L)

The tools that were used to achieve the objectives of the study were discussed through the ArcGIS program. It shows the importance of analyzing spatial and descriptive data in achieving the objectives of the study. Through the analysis on the IDW tool from the Map Arc tools, it was found that there is significant chemical pollution in groundwater wells in the Gaza Strip, up to multiple times according to international health standards. Table 4.2 Shows the summary of the results of the analyzes and their comparison with the standards of the World Health Organization.



Table 4.2 The summary of the results of the analyzes and their comparison with the standards of the WHO.

Name of Element	Code	A=The number of wells in(2015) compliant with WHO standards	B= The number of wells compliant with WHO standards	C= Total number of wells	Lowest percentage of well water that complies with the (WHO) standards (A÷C)×100	Highest percentage of well water that complies with the (WHO) standards (B÷C)×100	(WHO) Standards (mg/L)	Average concentration (mg/L)	Maximum concentrations (mg/L)	Maximum pollution level compared to WHO standards
Nitrate	NO ₃	17	38 (2007)	145	11.7% (2015)	26% (2007)	50	105	450	9 Times
Chloride	CL	31	49 (2007)	145	21.3% (2015)	34% (2007)	250	1300	10000	40 Times
Sodium	Na	44	63 (2007)	145	27.7% (2014)	42.8% (2007)	200	500	2000	10 Times
Potassium	K	29	141 (2007)	145	20% (2014)	97% (2007)	12	11	144	12 Times
Magnesium	Mg	27	138 (2007)	145	18% (2014)	95% (2007)	150	130	761	5 Times
Calcium	Ca	123	131 (2010)	145	85% (2015)	89.7% (2010)	200	158	700	4 Times
Hardness	Hardness	54	141 (2014)	145	37.2% (2015)	97% (2014)	600	900	4000	7 Times
Total Dissolved Solids	TDs	25	69 (2007)	145	17.2% (2015)	47.5% (2007)	1000	2900	19000	19 Times

4.5 The Amount of Precipitation and Its Effect on The Aquifer.

Rainwater is considered one of the most important sources of nutrition for underground reservoirs, and its reduced precipitation greatly affects the increase in groundwater pollution, and causes a large deficit in the process of withdrawal from the aquifer Figure 4.89 shows the rate of rainfall 2007-2015 Referring to the analysis maps for the year 2012, we find that the percentage of pollution decreased from the previous years, and this is due to the significant increase in rainfall for this year, and compared to that of other years.

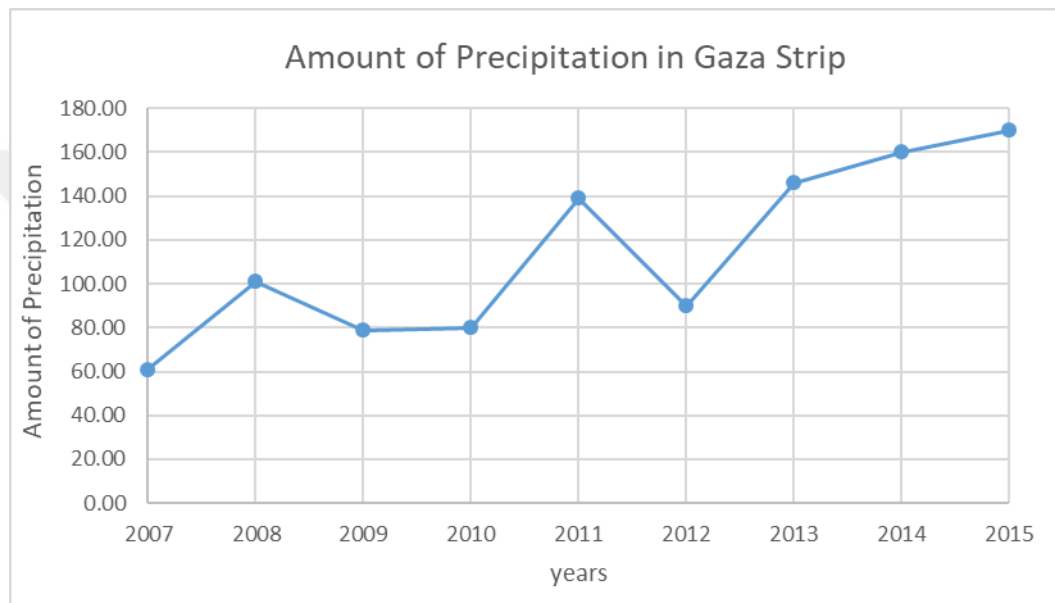


Figure 4.89 The Amount of rainfall (2007-2015)

4.6 Groundwater Level

The unbalanced hydrological situation between the withdrawal and feeding of the coastal aquifer has caused serious problems, including the drop in the water level in the reservoir and the deterioration of its water quality. This problem began in the period from 1935 to 1971 (Shameya,2012), and the reason is due to several factors, including influx of refugees into the Gaza Strip, in addition to the natural population increase, and agricultural expansion, all of which affected consumption rates, and consequently the water level, and the problem continued to exacerbate in 2014, analyzes proved that the level had fallen more than 10 meters below sea level, as shown in Figure 4.90.

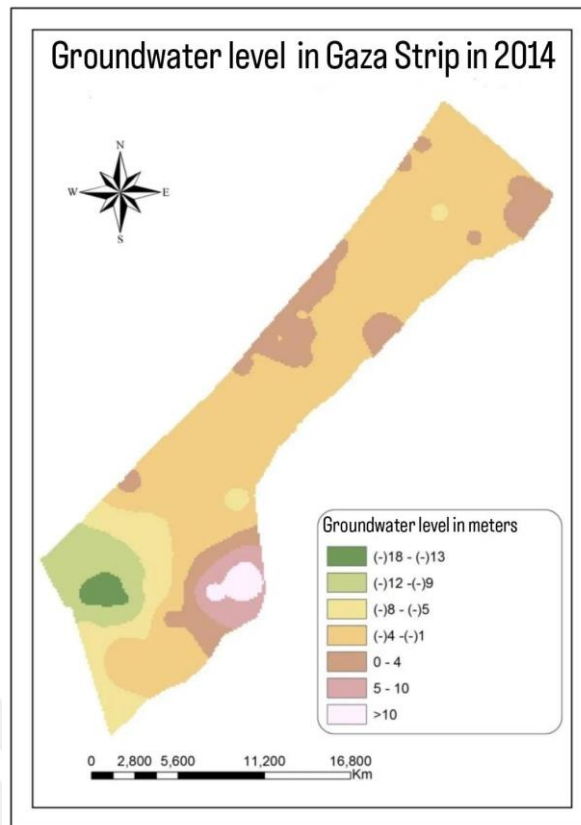


Figure 4.90 The Groundwater level in the Gaza strip in 2014

It is evident from Figure (4.34) that:

- The water level is very low, so we find that most sectors of the aquifer are located at a level between (-4_-1) meters above sea level, and this indicates that most of the underground reservoir is exposed to the interference of sea water.
- The eastern region of Khan Yuns governorate is considered the best area in the groundwater level, where the level of the aquifer relative to sea level reaches more than 10m. The lowest area in the level of the aquifer, it is located in the southwestern par from Rafah Governorate (-18_-13) m, which are dangerous levels that cause sea water to rapidly advance into the waters of the groundwater.

4.7 Model Management

4.7.1 Introduction

The transit model was developed based on the population growth rate in the strip and the concentrations of chemical elements from 2016 to 2021. Calibration of the groundwater flow model is an essential stage for predicting the concentration of the

elements referred to in this study in the future. The calibration results were reasonable by the numerical model that used the 3D finite difference method by GMS MODFLOW for the groundwater flow model and the MT3DMS code for the transport model. The groundwater head is an essential component of pollutant transfer monitoring. Excessive use of fertilizers in agricultural areas is a significant potential risk to groundwater quality. Moreover, over-pumping is a fundamental cause of low groundwater levels which led to drying out of the upper layers of the aquifer and an increase in the level of chemical element concentration in agricultural areas due to drought.

4.7.2 Current Situation Scenario

In fact, the process of studying this scenario begins with a description of the current hydrogeological characteristics of the aquifer, which lies in the identification of the basic problems aimed at in this research. The main problem to be addressed in this research is study of the Chemical element contamination behavior and their transfer to the aquifer by predicting the concentrations of chemical elements during the next thirty-five years. This scenario was studied using MT3DMS code with stress periods from 2025 to 2055. The transit model for this scenario was run as it is current situation (work as usual).

The management scenario is applied based on several of the following assumptions:

- 1- Stability of pumping rates during the stress period (2025-2055).
- 2- The mass loading rates of nitrogen used in fertilizers are kept fixed during the stress period. Hence, an increase in nitrate concentration was observed after some time near to cultivable lands.
- 3- Neglecting the chemical reaction process due to the lack of data, especially laboratory measurements in the Gaza Strip.
- 4- The climate change has not been needed for the simulation period.
- 5- Average population growth rate in the strip and the concentrations of chemical elements from 2016 to 2021.

In this scenario, two wells with different purposes were selected from each governorate to study the impact of the management scenario on the concentration of chemical elements over the years (2025, 2030, 2035, 2040, 2045, 2050, 2055).

4.7.2.1 Nitrate "NO₃".

This scenario simulates the work as usual without any change neither in the groundwater flow characteristics nor the transport coefficients during the simulation period from 2025-2055. The simulation results shown in Table 4.3 and figures 4.91,4.92,4.93 show that there is an increase in the concentration of NO₃ in the wells located in the agricultural areas where the concentration reached nearly 1304.01 mg/L after 35 years. This is clear evidence of the deterioration of groundwater quality. The average expected annual increase in NO₃ concentration was estimated at about 10.16 mg/L over the Gaza Strip.

Table 4.3 Amount of NO₃ (mg/l) concentration for the scenario "current situation" (2025, 2030, 2035, 2040,2045,2050 and 2055) years.

Well Id	Sector	2025	2030	2035	2040	2045	2050	2055
Ad-Allah	central	173.54	207.64	200.20	204.34	217.29	238.51	267.89
Al -shoot	central	188.54	222.64	253.64	284.64	315.64	346.64	377.64
Al -soode	Gaza	229.54	263.64	384.99	470.60	543.02	602.26	636.26
L/127	Gaza	190.54	219.54	248.54	277.54	306.54	335.54	364.54
L/176	Khan	237.54	268.54	299.54	330.54	361.54	392.54	423.54
P/153	Khan	366.54	616.24	855.18	1067.60	1234.78	1329.11	1304.01
Q/68	North	221.54	377.69	526.69	660.78	769.45	836.60	834.77
R/343	North	138.54	167.54	196.54	225.54	254.54	283.54	312.54
R/344	Rafah	172.54	206.64	261.21	304.57	346.16	385.69	417.29
S/90	Rafah	161.54	195.64	233.86	278.00	313.00	348.00	383.00
	Average	208.04	274.57	346.04	410.41	466.20	509.84	532.15

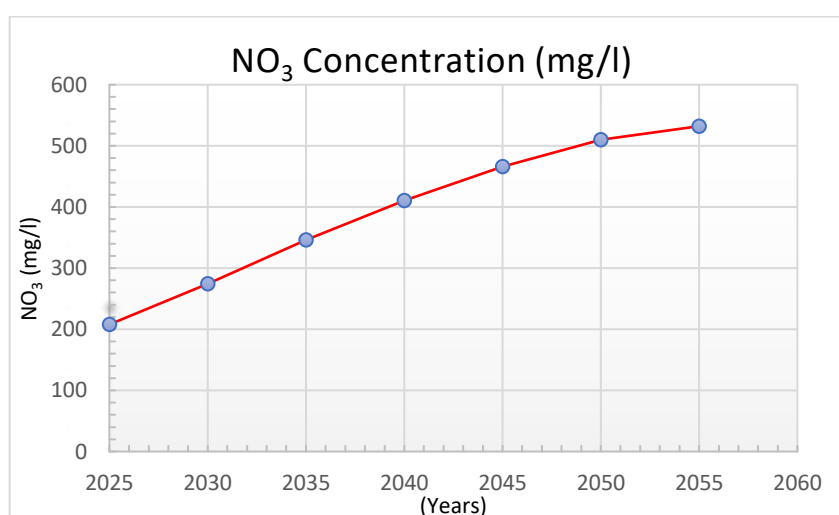


Figure 4.91 NO₃ concentration for the scenario "current situation" (2025, 2030, 2035, 2040,2045,2050 and 2055) years

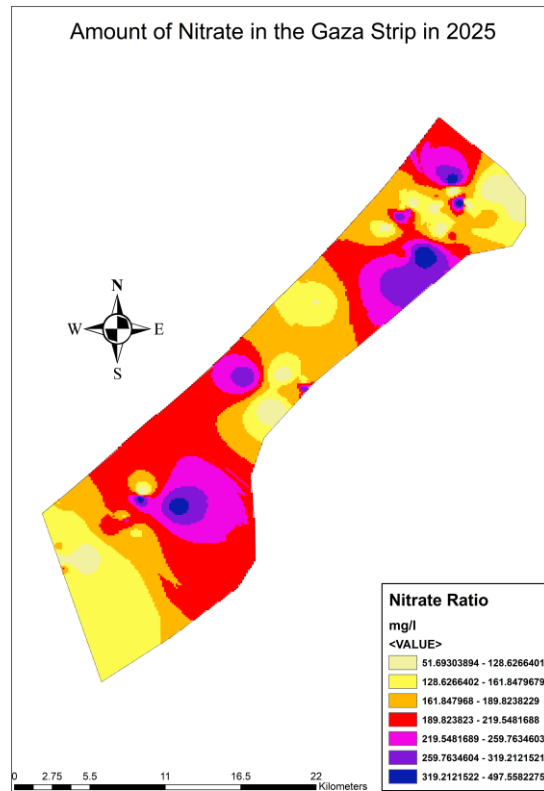


Figure 4.92 Nitrate concentration for year 2025 according to management scenario

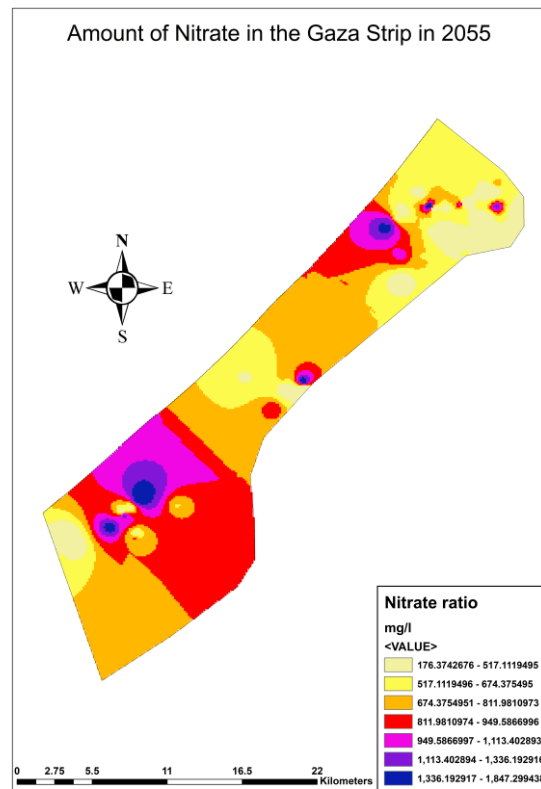


Figure 4.93 Nitrate concentration for year 2055 according to management scenario

4.7.2.2 Chloride "CL".

The simulation results shown in Table 4.4 and figures 4.94,4.95,4.96 show that there is an increase in the concentration of CL in the wells located in the agricultural areas where the concentration reached nearly 5366.20 mg/L after 35 years. This is clear evidence of the deterioration of groundwater quality. The average expected annual increase in CL concentration was estimated at about 65 mg/L over the Gaza Strip.

Table 4.4 Amount of Chloride (mg/l) concentration for the scenario "current situation" (2025, 2030, 2035, 2040,2045,2050 and 2055) years.

Well Id	Sector	2025	2030	2035	2040	2045	2050	2055
Ad-Allah	Central	1554.86	1706.14	2643.98	3288.30	3804.38	4188.94	4364.04
Al-shoot	Central	1173.86	1325.14	2243.90	2876.15	3383.42	3762.34	3936.76
Al-soode	Gaza	800.86	952.14	1101.14	1250.14	1399.14	1548.14	1697.14
L/127	Gaza	1104.86	2184.04	3226.21	4153.00	4877.28	5274.52	5144.86
L/176	Khan	442.86	563.86	684.86	805.86	926.86	1047.86	1168.86
P/153	Khan	1023.86	2116.62	3194.63	4153.69	4900.13	5297.25	5106.23
Q/68	North	227.50	315.50	403.50	491.50	579.50	667.50	755.50
R/343	North	478.86	597.86	716.86	835.86	954.86	1073.86	1192.86
R/344	Rafah	994.86	1146.14	2723.13	3778.51	4594.09	5169.38	5366.20
S/90	Rafah	341.86	493.14	688.38	952.00	1375.50	2184.33	4186.00
	Average	814.42	1140.06	1762.66	2258.50	2679.51	3021.41	3291.84

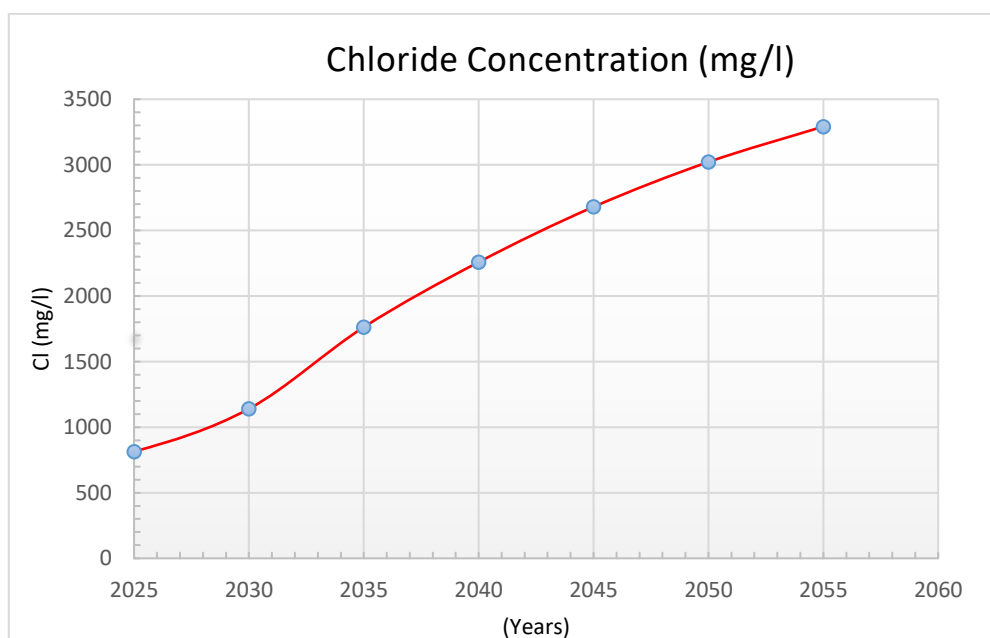


Figure 4.94 Chloride concentration for the scenario "current situation" (2025, 2030, 2035, 2040,2045,2050 and 2055) years

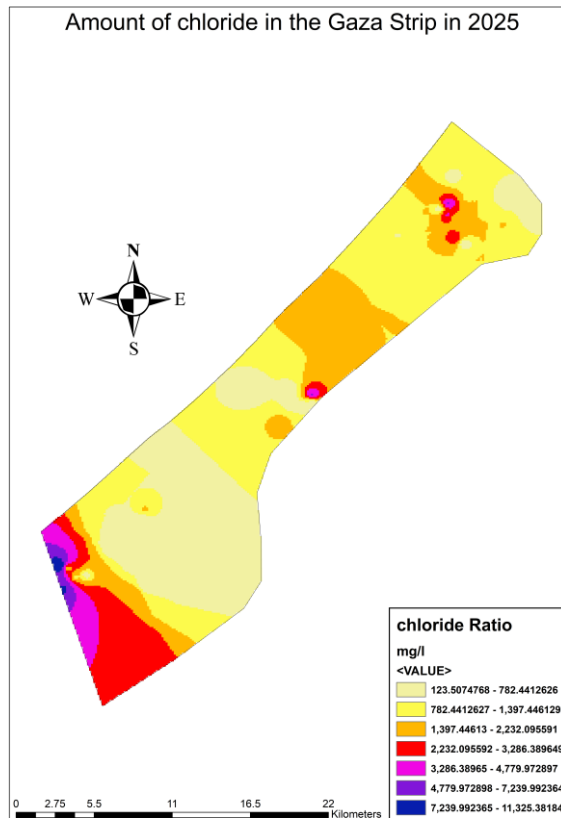


Figure 4.95 Chloride concentration for year 2025 according to management scenario

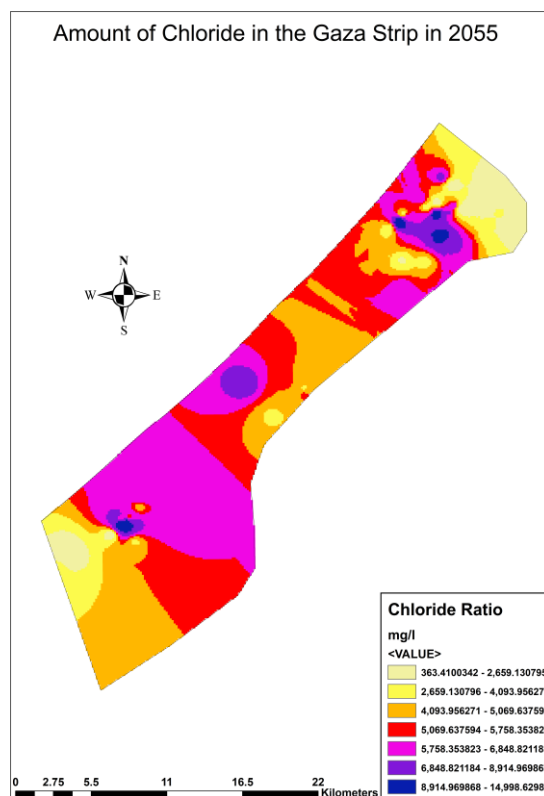


Figure 4.96 Chloride concentration for year 2055 according to management scenario

4.7.2.3 Sodium "Na".

The simulation results shown in Table 4.5 and figures 4.97,4.98,4.99 show that there is an increase in the concentration of Na in the wells located in the agricultural areas where the concentration reached nearly 4315.64 mg/L after 35 years. This is clear evidence of the deterioration of groundwater quality. The average expected annual increase in Na concentration was estimated at about 39 mg/L over the Gaza Strip.

Table 4.5 Amount of Na (mg/l) concentration for the scenario "current situation"(2025, 2030, 2035, 2040,2045,2050 and 2055) years.

Well Id	Sector	2025	2030	2035	2040	2045	2050	2055
Ad-Allah	central	242.00	269.00	482.40	626.60	740.80	822.26	852.96
Al - shoot	central	912.86	1037.86	1703.06	2169.47	2547.43	2834.03	2957.74
Al - soode	Gaza	662.86	787.86	903.86	1019.86	1135.86	1251.86	1367.86
L/127	Gaza	882.86	1737.46	2602.68	3370.83	3972.42	4301.67	4185.20
L/176	Khan	347.86	469.86	591.86	713.86	835.86	957.86	1079.86
P/153	Khan	912.86	1824.79	2724.89	3538.78	4179.73	4519.57	4315.64
Q/68	North	133.93	176.93	219.93	262.93	305.93	348.93	391.93
R/343	North	402.86	529.86	656.86	783.86	910.86	1037.86	1164.86
R/344	Rafah	587.86	712.86	1282.66	1739.15	2105.27	2392.18	2485.53
S/90	Rafah	267.50	389.29	584.52	740.00	865.00	990.00	1115.00
	Average	535.34	793.57	1175.27	1496.53	1759.91	1945.62	1991.66

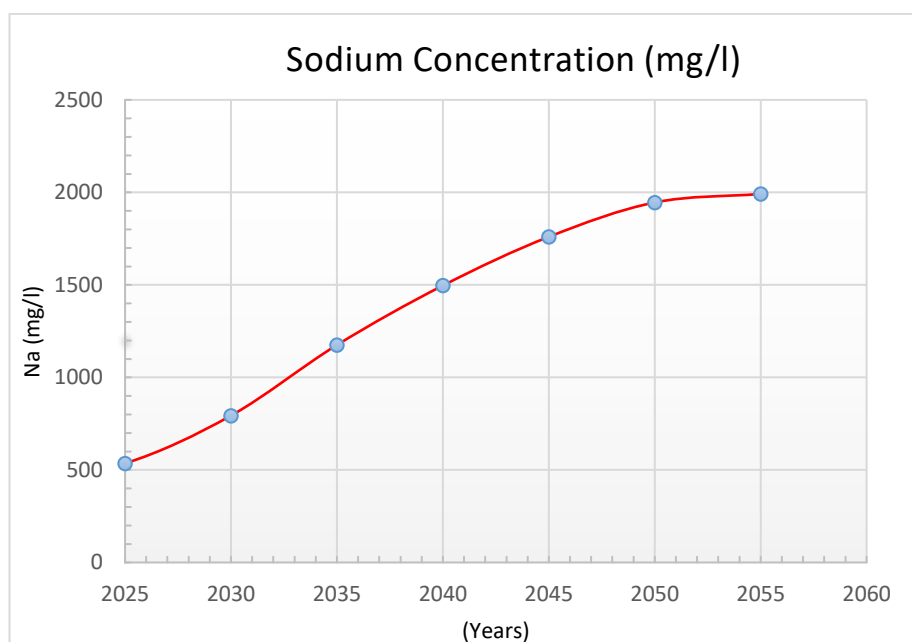


Figure 4.97 Sodium concentration for the scenario "current situation" (2025, 2030,2035, 2040,2045,2050 and 2055) years

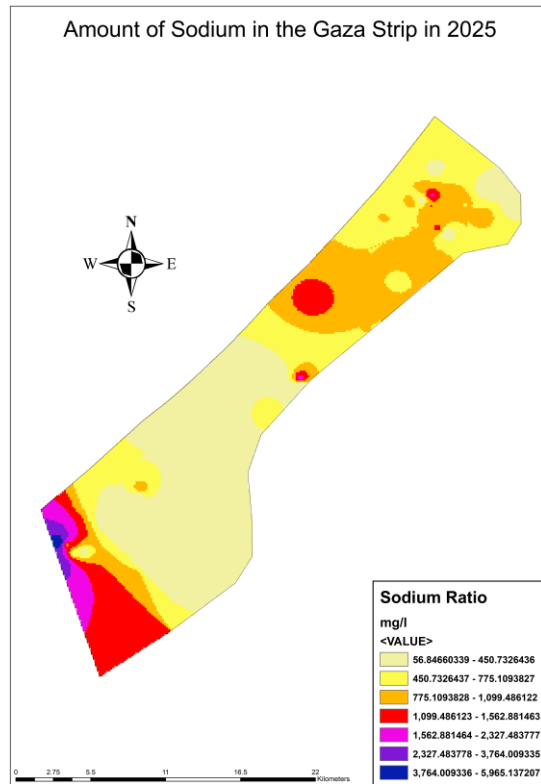


Figure 4.98 Sodium concentration for year 2025 according to management scenario

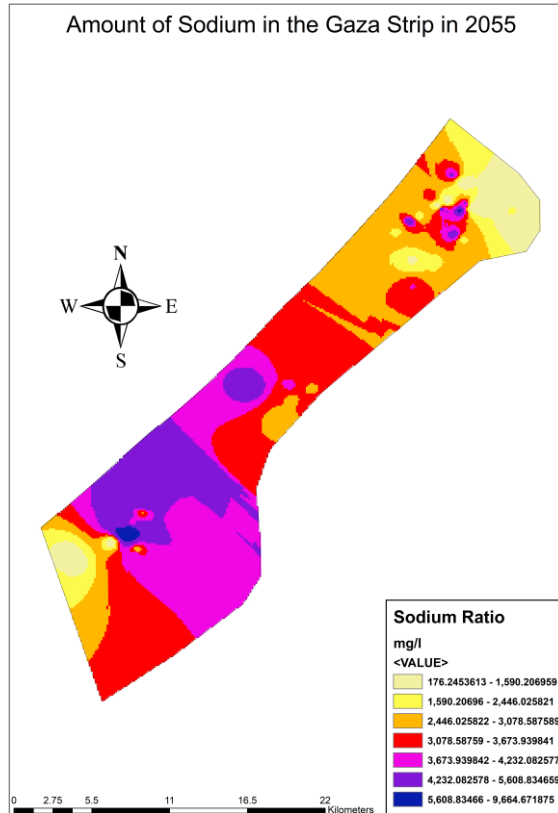


Figure 4.99 Sodium concentration for year 2055 according to management scenario

4.7.2.4 Potassium "K".

The simulation results shown in Table 4.6 and figures 4.100,4.101,4.102 show that there is an increase in the concentration of Potassium in the wells located in the agricultural areas where the concentration reached nearly 63.5 mg/L after 35 years. This is clear evidence of the deterioration of groundwater quality. The average expected annual increase in Potassium concentration was estimated at about 0.67 mg/L over the Gaza Strip.

Table 4.6 Amount of Potassium (mg/l) concentration for the scenario "current situation" (2025, 2030, 2035, 2040,2045,2050 and 2055) years.

Well Id	Sector	2025	2030	2035	2040	2045	2050	2055
Ad-Allah	central	14.97	20.20	19.26	20.21	22.71	26.15	29.61
Al - shoot	central	15.97	21.20	22.65	25.11	28.71	32.85	36.39
Al - soode	Gaza	15.97	21.20	29.80	38.47	46.45	53.22	56.22
L/127	Gaza	8.94	9.91	11.97	14.17	16.71	19.41	21.34
L/176	Khan	8.94	9.31	9.52	10.16	11.61	14.22	18.33
P/153	Khan	13.37	17.39	21.96	26.99	31.95	35.82	36.61
Q/68	North	4.15	4.43	5.32	6.20	7.19	8.18	10.75
R/343	North	8.94	12.14	15.34	18.54	21.74	24.94	28.14
R/344	Rafah	16.97	22.20	33.19	43.36	52.44	59.92	63.50
S/90	Rafah	5.83	8.34	11.86	17.60	33.00	38.00	43.00
	Average	11.41	14.63	18.09	22.08	27.25	31.27	34.39

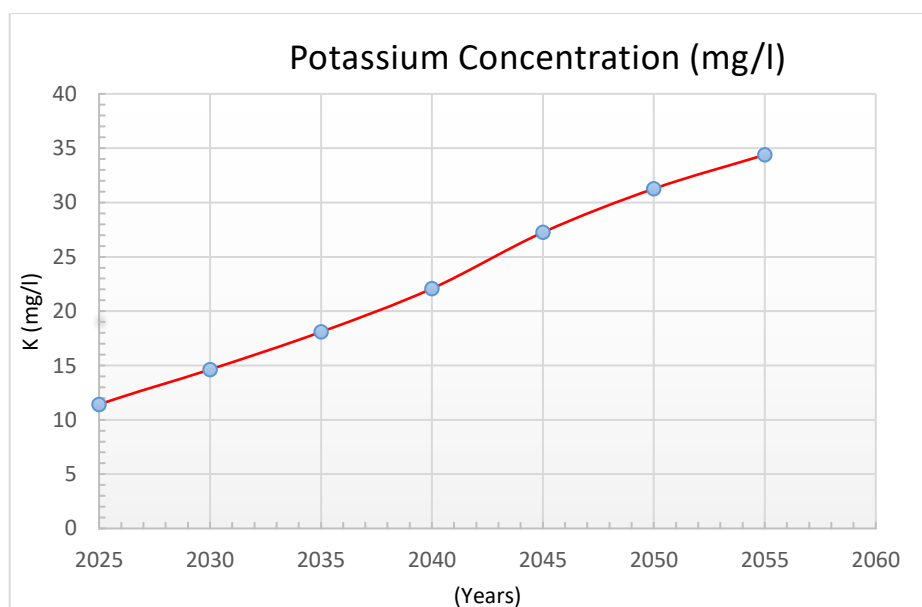


Figure 4.100 Potassium concentration for the scenario "current situation" (2025, 2030, 2035, 2040,2045,2050 and 2055) years

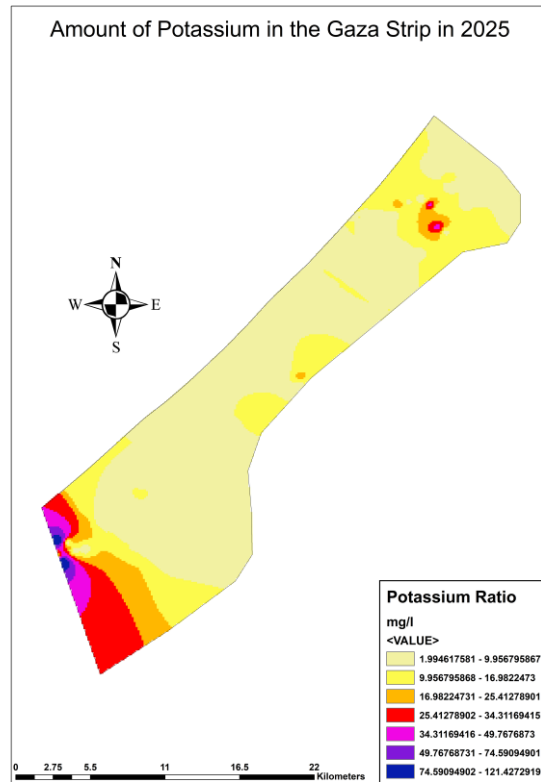


Figure 4.101 Potassium concentration for year 2025 according to management scenario

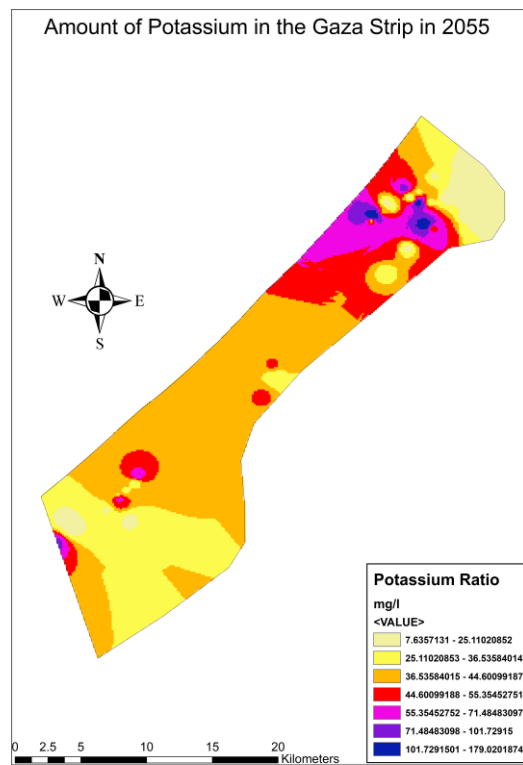


Figure 4.102 Potassium concentration for year 2055 according to management scenario

4.7.2.5 Magnesium "Mg".

The simulation results shown in Table 4.7 and figures 4.103,4.104,4.105 show that there is an increase in the concentration of Magnesium in the wells located in the agricultural areas where the concentration reached nearly 891.61 mg/L after 35 years. This is clear evidence of the deterioration of groundwater quality. The average expected annual increase in Magnesium concentration was estimated at about 8.26 mg/L over the Gaza Strip.

Table 4.7 Amount of Magnesium (mg/l) concentration for the scenario "current situation" (2025, 2030, 2035, 2040,2045,2050 and 2055) years.

Well Id	Sector	2025	2030	2035	2040	2045	2050	2055
Ad-Allah	central	242.00	269.00	482.40	626.60	740.80	822.26	852.96
Al - shoot	central	161.00	188.00	358.48	475.51	569.88	638.68	667.84
Al - soode	Gaza	98.00	125.00	116.61	120.49	132.25	148.25	170.99
L/127	Gaza	110.00	161.14	209.35	256.40	297.57	329.42	346.27
L/176	Khan	92.00	118.00	144.00	170.00	196.00	222.00	248.00
P/153	Khan	137.00	204.74	268.91	329.85	381.40	418.08	430.80
Q/68	North	108.00	131.98	154.08	178.39	202.57	226.53	250.14
R/343	North	108.00	134.00	160.00	186.00	212.00	238.00	264.00
R/344	Rafah	184.00	211.00	455.41	632.66	769.77	867.98	891.61
S/90	Rafah	54.50	78.86	117.90	149.00	174.00	199.00	224.00
	Average	129.45	162.17	246.71	312.49	367.62	411.02	434.66

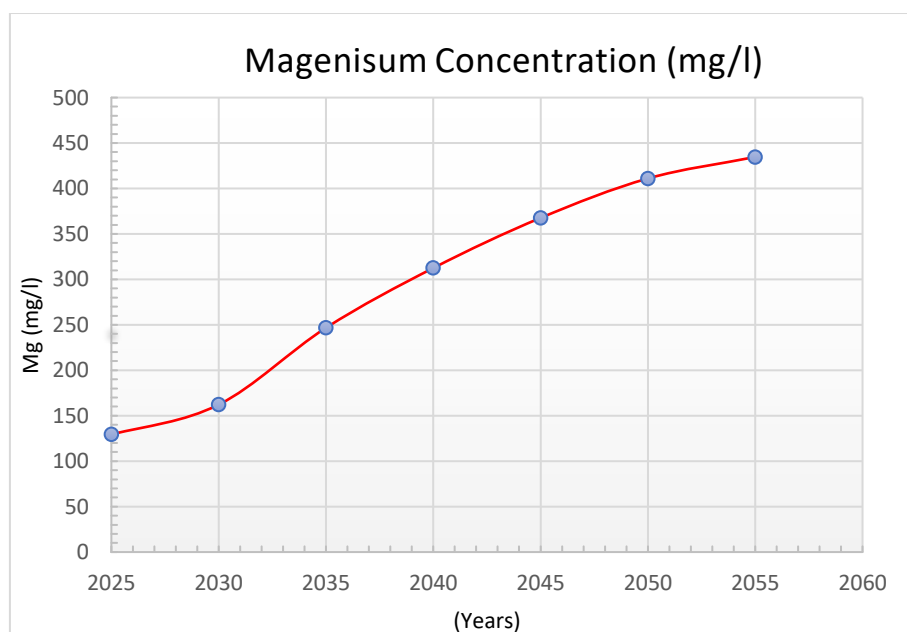


Figure 4.103 Magnesium concentration for the scenario "current situation" (2025, 2030, 2035, 2040,2045,2050 and 2055) years

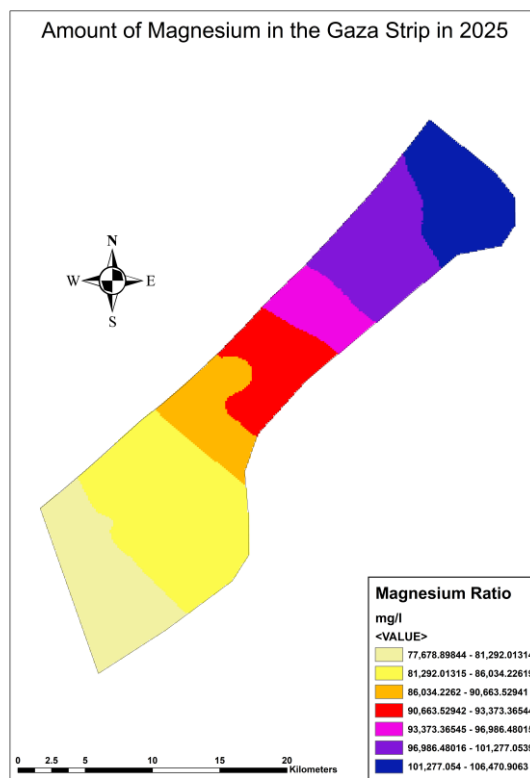


Figure 4.104 Magnesium concentration for year 2025 according to management scenario

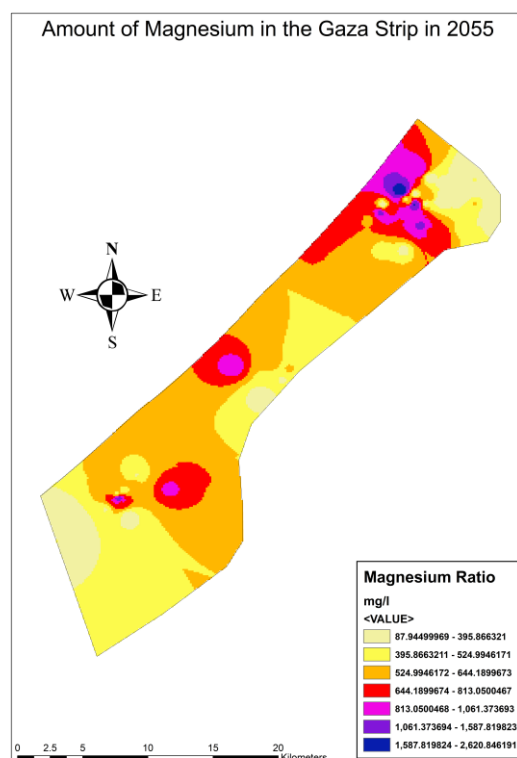


Figure 4.105 Magnesium concentration for year 2055 according to management scenario

4.7.2.6 Calcium "Ca".

The simulation results shown in Table 4.8 and figures 4.106,4.107,4.108 show that there is an increase in the concentration of Calcium in the wells located in the agricultural areas where the concentration reached nearly 817.5 mg/L after 35 years. This is clear evidence of the deterioration of groundwater quality. The average expected annual increase in Calcium concentration was estimated at about 8.39 mg/L over the Gaza Strip.

Table 4.8 Amount of Calcium (mg/l) concentration for the scenario "current situation" (2025, 2030, 2035, 2040,2045,2050 and 2055) years

Well Id	Sector	2025	2030	2035	2040	2045	2050	2055
Ad-Allah	central	233.00	258.00	423.71	537.72	627.71	694.24	724.29
Al - shoot	central	174.00	199.00	321.78	408.64	478.80	532.66	561.17
Al - soode	Gaza	133.00	158.00	273.63	355.96	422.82	474.56	502.81
L/127	Gaza	95.00	118.00	141.00	164.00	187.00	210.00	233.00
L/176	Khan	175.00	222.63	269.39	313.34	352.50	384.08	403.45
P/153	Khan	160.00	194.05	227.76	260.34	291.00	318.63	341.38
Q/68	North	154.00	237.84	319.42	393.69	455.50	497.60	507.96
R/343	North	115.00	141.00	167.00	193.00	219.00	245.00	271.00
R/344	Rafah	175.00	200.00	415.79	578.30	702.16	788.69	817.50
S/90	Rafah	85.00	110.00	135.00	160.00	185.00	210.00	235.00
	Average	149.90	183.85	269.45	336.50	392.15	435.55	459.76

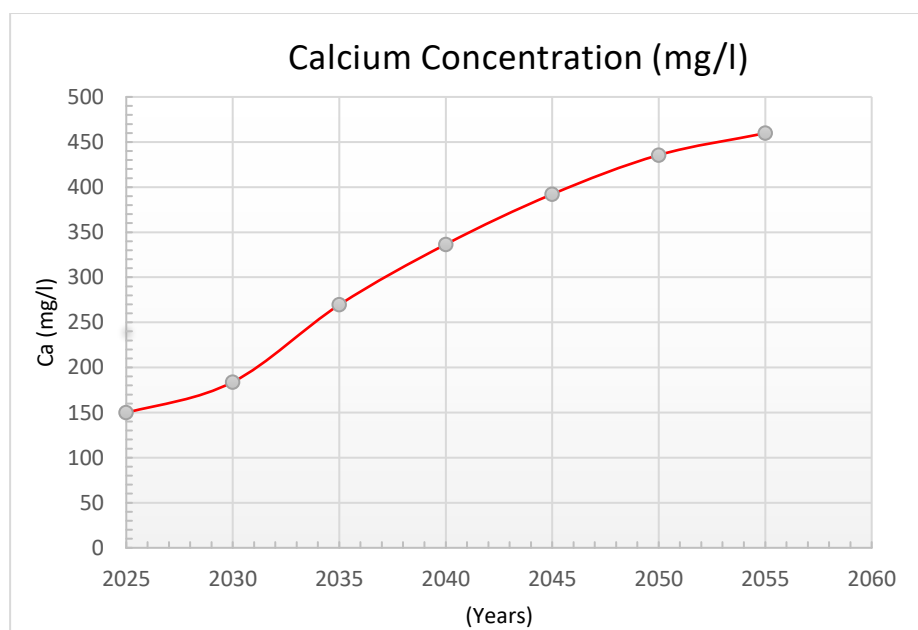


Figure 4.106 Calcium concentration for the scenario "current situation" (2025, 2030, 2035, 2040,2045,2050 and 2055) years

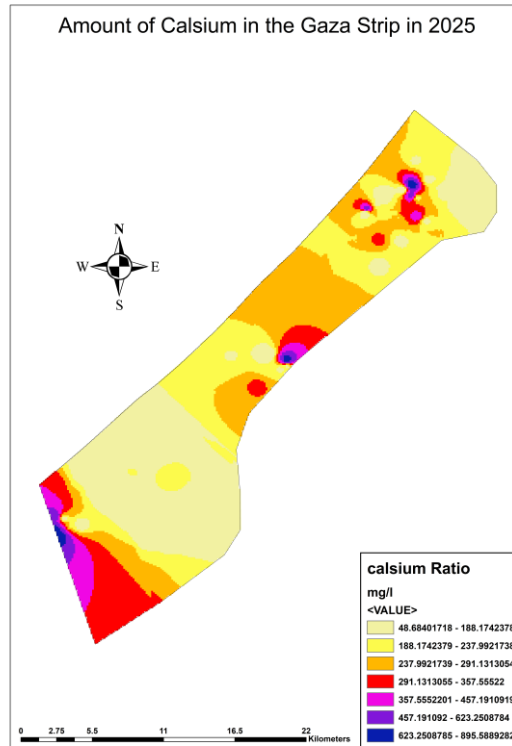


Figure 4.107 Calcium concentration for year 2025 according to management scenario

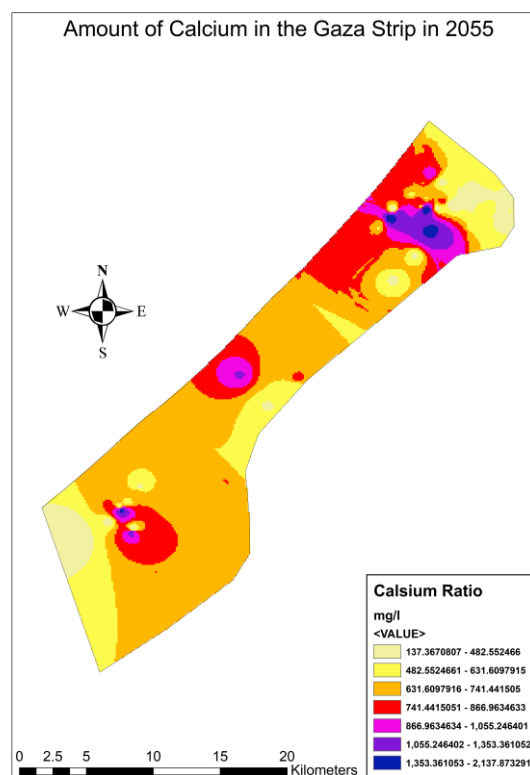


Figure 4.108 Calcium concentration for year 2055 according to management scenario

4.7.2.7 Hardness.

The simulation results shown in Table 4.9 and figures 4.109,4.110,4.111 show that there is an increase in the concentration of Hardness in the wells located in the agricultural areas where the concentration reached nearly 5750.59 mg/L after 35 years. This is clear evidence of the deterioration of groundwater quality. The average expected annual increase in Hardness concentration was estimated at about 46.76 mg/L over Gaza Strip.

Table 4.9 Amount of Hardness (mg/l) concentration for the scenario "current situation" (2025, 2030, 2035, 2040,2045,2050 and 2055) years

Well Id	Sector	2025	2030	2035	2040	2045	2050	2055
Ad-Allah	central	1491.61	1621.07	2878.27	3713.89	4363.16	4823.98	4983.64
Al - shoot	central	1010.61	1140.07	2106.32	2757.87	3272.75	3647.69	3796.93
Al - soode	Gaza	651.61	781.07	1005.63	1187.96	1360.26	1516.30	1638.92
L/127	Gaza	603.61	721.61	839.61	957.61	1075.61	1193.61	1311.61
L/176	Khan	730.61	849.61	968.61	1087.61	1206.61	1325.61	1444.61
P/153	Khan	878.61	1203.30	1514.89	1803.68	2052.46	2231.33	2297.57
Q/68	North	742.61	1008.45	1263.47	1502.98	1714.96	1876.73	1957.61
R/343	North	645.61	769.61	893.61	1017.61	1141.61	1265.61	1389.61
R/344	Rafah	1106.61	1236.07	2955.94	4101.06	4974.77	5577.35	5750.59
S/90	Rafah	421.61	551.07	685.00	810.00	935.00	1060.00	1185.00
	Average	828.31	988.19	1511.13	1894.03	2209.72	2451.82	2575.61

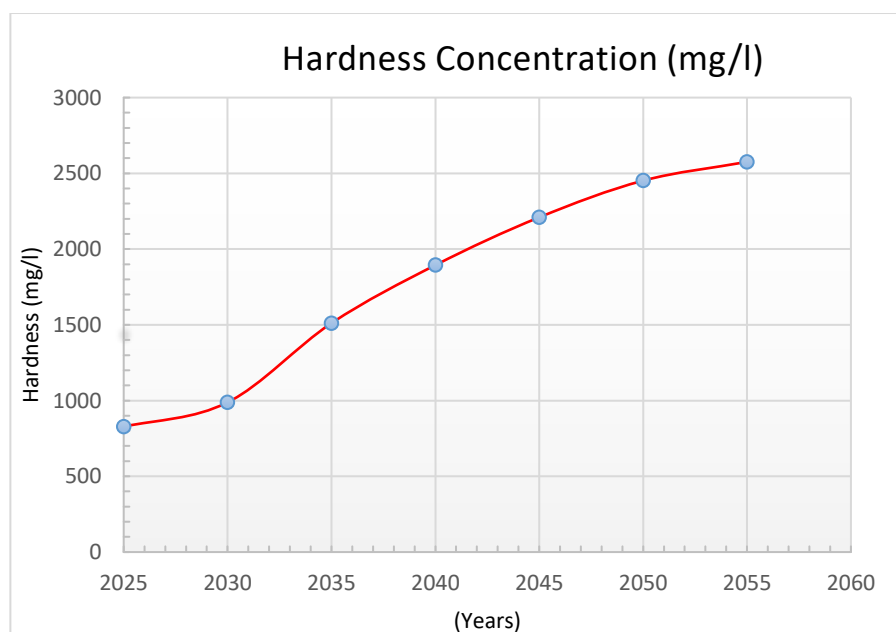


Figure 4.109 Hardness concentration for the scenario "current situation" (2025, 2030, 2035, 2040,2045,2050 and 2055) years

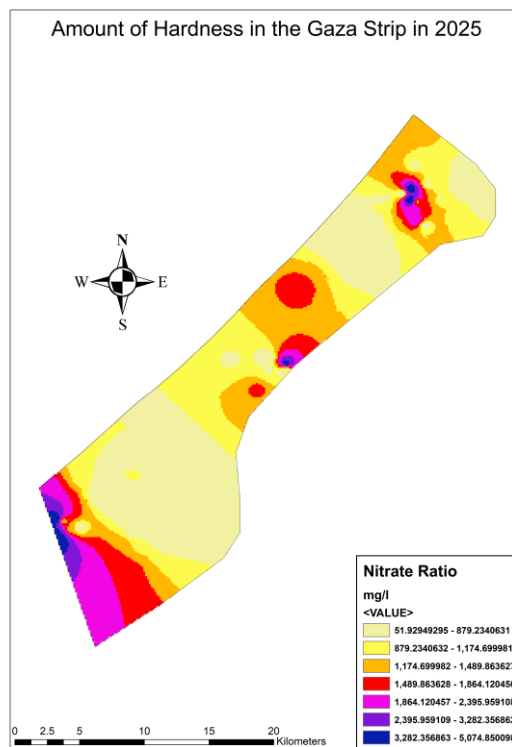


Figure 4.110 Hardness concentration for year 2025 according to management scenario

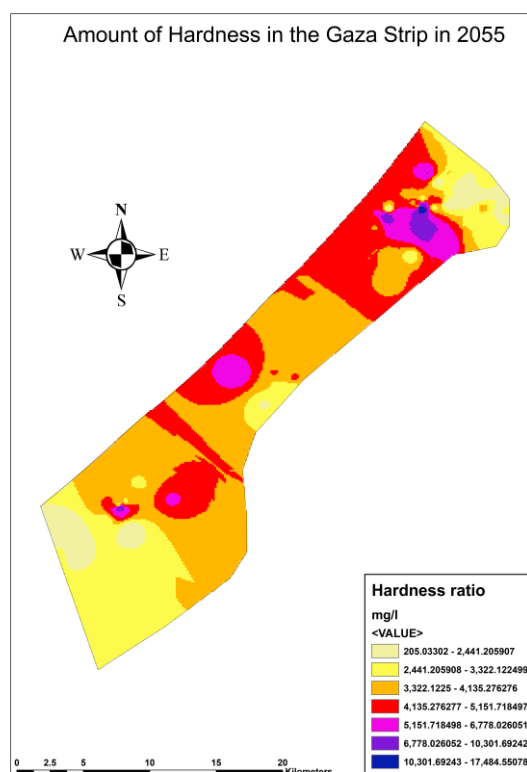


Figure 4.111 Hardness concentration for year 2055 according to management scenario

4.7.2.8 Total Dissolved Solids "TDS".

The simulation results shown in Table 4.10 and figures 4.112,4.113,4.114 show that there is an increase in the concentration of Total Dissolved Solids in the wells located in the agricultural areas where the concentration reached nearly 13179.04 mg/L after 35 years. This is clear evidence of the deterioration of groundwater quality. The average expected annual increase in Total Dissolved Solids concentration was estimated at about 141.1 mg/L over the Gaza Strip.

Table 4.10 Amount of TDs (mg/l) concentration for the scenario "current situation" (2025, 2030, 2035, 2040,2045,2050 and 2055) years

Well Id	Sector	2025	2030	2035	2040	2045	2050	2055
Ad-Allah	central	3914.75	4183.50	6528.24	8100.13	9319.71	10202.34	10566.88
Al - shoot	central	2971.75	3240.50	5167.88	6475.74	7502.56	8262.01	8611.58
Al - soode	Gaza	2203.75	2472.50	2652.50	2832.50	3012.50	3192.50	3372.50
L/127	Gaza	2748.75	5027.56	7228.91	9175.78	10687.04	11509.33	11221.72
L/176	Khan	1347.75	1560.75	1773.75	1986.75	2199.75	2412.75	2625.75
P/153	Khan	2854.75	5667.67	8382.55	10776.70	12622.04	13599.54	13179.04
Q/68	North	1099.75	1276.75	1453.75	1630.75	1807.75	1984.75	2161.75
R/343	North	1409.75	1699.00	1988.25	2277.50	2566.75	2856.00	3145.25
R/344	Rafah	2327.75	2596.50	6143.21	8475.51	10250.26	11487.66	11895.30
S/90	Rafah	880.75	1149.50	1503.67	2017.00	2859.50	4495.33	8587.00
	Average	2175.95	2887.42	4282.27	5374.84	6282.79	7000.22	7536.68

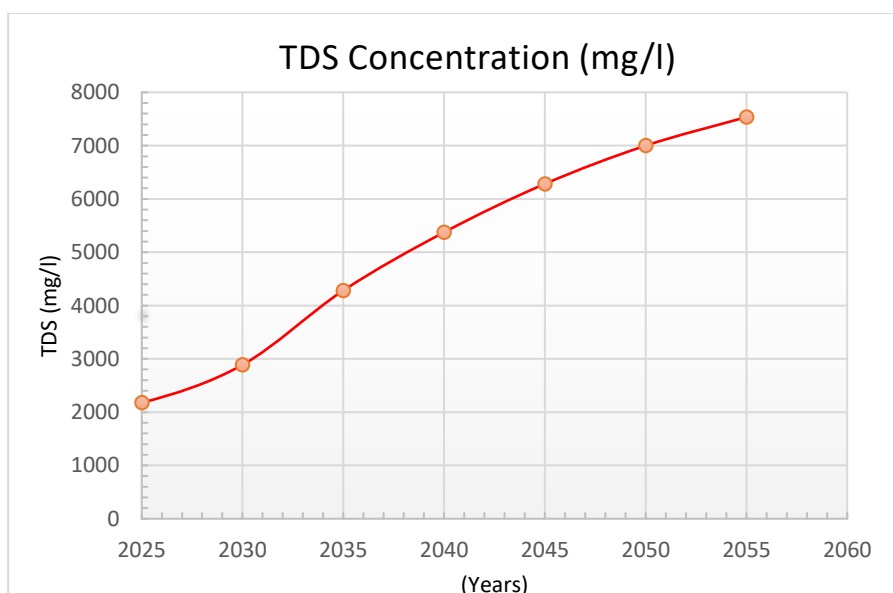


Figure 4.112 Total Dissolved Solids concentration for the scenario "current situation" (2025, 2030, 2035, 2040,2045,2050 and 2055) years

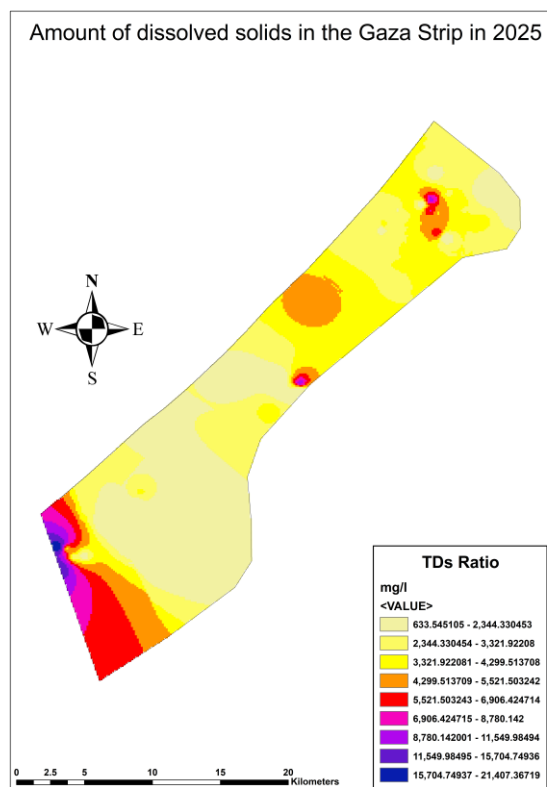


Figure 4.113 TDs concentration for year 2025 according to management scenario

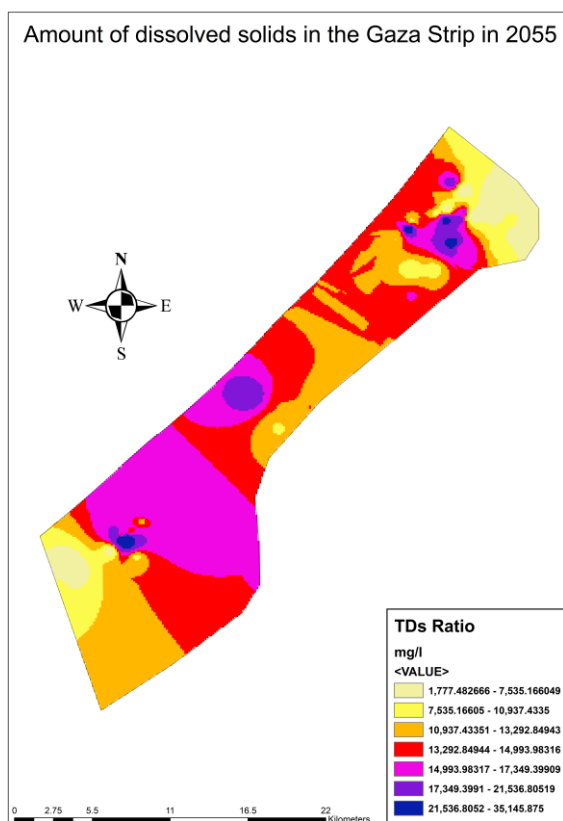


Figure 4.114 Hardness concentration for year 2055 according to management scenario

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 General.

The problem of environmental pollution is one of the most serious problems that threaten our planet due to its relationship to human activity, and among these pollutants that threaten man and his daily life is what is known as water pollution. We find that the problem of water pollution in the Gaza Strip is growing steadily due to several factors, both natural and human. The study aimed to use GIS technology to compare and monitor groundwater properties data over the past years and to provide a model for chemical properties through the tools of the ArcGIS program, with the aim of conducting some spatial and descriptive analyzes. The study focused on 145 municipal wells, distributed over all Gaza governorates.

5.2 Conclusions.

- 1) The ability of geographic information systems to study, evaluate and analyze the characteristics of the water situation, produce accurate maps that show pollution rates, and establish geographical databases for the chemical properties of drinking water in the study area.
- 2) The percentage of groundwater pollution with nitrate has increased to three times the percentage recommended by the World Health Organization, and the percentage of usable wells (municipal wells) does not exceed 12% for the year 2015.
- 3) The rate of groundwater contamination with chloride has increased to five times the percentage recommended by the World Health Organization, and the percentage of usable wells (municipal wells) does not exceed 21.3% for the year 2015.
- 4) The level of groundwater pollution with sodium has increased to three times the percentage recommended by the World Health Organization.

- 5) The percentage of groundwater pollution with water hardness has increased to four times the percentage recommended by the World Health Organization, and the percentage of usable wells (municipal wells) does not exceed 37.2% for the year 2015.
- 6) The high percentage of groundwater pollution with the components of dissolved solids and electrical conductivity to four times the percentage recommended by the World Health Organization, and that the percentage of usable wells (municipal wells) does not exceed 18% for the year 2015.
- 7) There is a correlation between chemical water pollution and the high incidence of liver - kidney - nervous system diseases) and other diseases.
- 8) A drop in the level of the groundwater compared to the level of the sea, which led to the overlap of sea water into the aquifer, and an increase in the rates of chemical pollution of groundwater.
- 9) The beach of Gaza Governorate suffers from the process of pumping wastewater, which has a noticeable impact on the pollution of groundwater wells in the governorate and a significant increase in the rates of chemical pollution of water, the impact of sea water overlap in the aquifer.
- 10) There is an inverse relationship between the increase in the amount of precipitation and the decrease in the rates of chemical pollution of groundwater.
- 11) The results showed that the aquifer suffers from a sharp decline in the water level and dramatic increase in the concentration of chemical elements after 35 years, especially in the southern areas of the Gaza Strip.
- 12) Moreover, excessive pumping effects on the rates of chemical elements concentration, but the effects are not considerably as compared with reduction of chemical elements fertilizers loading at cultivate areas.

5.3 Recommendations

- 1) The necessity of using geographic information systems in all local institutions to benefit from them in the process of producing databases and maps.
- 2) The necessity of adopting policies that preserve the coastal aquifer in the Gaza Strip, given that it is the only source for the population of the Strip.
- 3) It is necessary that the proportions of chemical analyzes match what was recommended by the World Health Organization.

- 4) The researcher recommends the formation of committees at the level of ministries, municipalities, the village council, and NGOs, to adopt a policy of spreading a health culture in the use of water among citizens, warn them of the harmful effects of using polluted water on their health, and reduce water waste.
- 5) The necessity of having accurate knowledge of groundwater problems in the community and not being limited to having general knowledge that does not contribute to limiting the problem.
- 6) Paying attention as much as possible to popular participation and taking ideas and criticisms, because every eye has a look, and because the people who know the most about the problem are the ones who suffer from it.
- 7) Developing the site to include all the governorates of the country.
- 8) Relevant institutions adopt the site to store and publish information in it.
- 9) Reducing the pumping rate of municipal wells according to the sustainable water supply program in Gaza beyond 2022.
- 10) Reducing the percentage of nitrogen used in fertilizers loaded in agricultural areas by 50%.
- 11) Prevention of pumping wells drilling in depression regions and regions that have high rates of nitrate concentration, as it affects the groundwater quality.
- 12) Many random and illegal agriculture wells have caused a decrease in water level should be closed or used as injection wells to increase the recharge.

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APPENDIX

Table B.1 Amount of production of groundwater wells in the governorates of Gaza.

Production (m ³ /year)										
Zone	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
North	17,945,010	19,449,159	22,017,871	22,473,206	21,996,621	24,317,742	24,543,210	22,989,511	23,025,514	21,510,136
Beit Hanon	2,926,251	3,187,180	3,857,720	3,633,717	3,942,220	4,207,170	4,280,570	3,787,360	3,627,180	3,583,640
Beit Lahia	4,360,712	4,951,863	5,327,148	5,875,188	6,006,474	6,692,288	6,154,743	6,607,013	6,537,401	6,073,640
Jabalia	10,590,227	11,145,836	12,621,689	12,748,141	11,826,921	13,082,746	13,692,384	12,434,299	12,634,683	11,580,176
Om ElNasser	67,820	164,280	211,314	216,160	221,006	174,750	169,970	179,820	226,250	272,680
Gaza	28,521,411	28,345,583	29,921,704	33,992,726	34,134,466	34,310,987	36,053,582	38,733,141	46,903,998	28,072,084
ElZahra		281,180	372,330	461,310	459,886	373,325	454,350	661,608	408,355	417,163
ElMoghraqa	176,280	320,983	417,671	503,673	627,680	781,033	700,675	710,850	659,290	645,960
Wadi Gaza		62,630	74,140	46,770	71,660			159,020	104,453	159,020
Middle	8,245,510	7,453,111	10,715,483	8,427,258	9,633,648	10,594,952	13,790,049	12,104,368	13,596,943	14,849,471
Al Nussierat	1,706,366	1,500,518	2,922,833	2,874,334	1,771,083	2,388,510	3,441,820	3,226,550	4,129,855	5,033,160
AL Burij	1,796,702	1,500,880	1,198,550	438,814	839,333	1,002,790	1,284,796	1,077,240	1,510,567	1,943,894
Al Maghazy	397,190	402,612	1,237,501	1,016,164	993,556	1,012,604	1,068,112	1,371,442	1,480,283	1,035,452
AL Zawaida	40,874	219,699	986,220	817,567	1,183,412	1,269,865	886,559	1,217,897	1,159,416	1,008,751
AL Mossader		14,210	107,290	111,620	119,110	149,930	160,850	159,014	167,750	176,486
Dair Al Balah	4,304,378	3,494,209	4,263,089	3,168,759	4,727,154	4,771,253	4,161,530	5,052,225	4,740,717	4,446,800
AL Qrarar	593,510	659,705	915,298	890,411	856,495	807,960	1,013,679	1,095,506	1,408,158	1,720,810
Khanyouni	9,104,543	9,837,095	9,771,395	8,873,048	8,659,572	7,956,889	9,343,243	8,964,594	9,518,328	8,747,227

Zone	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
EastrenArea Khanyouni	449,790	193,320	1,319,090	200,070	260,650	210,030	1,577,415	1,211,720	1,323,080	902,850
Eastren Area Wells			2,002,270					2,726,911	888,945	902,770
Al Fukhary		459,730	315,697	325,920	318,080	311,989	324,520	334,720	286,648	248,270
Rafah	6,210,008	6,288,425	6,051,523	6,168,029	6,810,612	6,336,313	7,758,369	7,979,308	8,583,893	8,589,787
AL Nasser		115,210	119,860	155,041	201,628	291,972	286,850	356,440	439,190	
AL Shuka		214,800	332,900	490,040	506,380	324,383	1,000,901	705,397	517,180	518,259
MEKORO T	3,641,000	4,628,527	6,924,147	6,924,147	7,923,625	5,775,248	5,503,325	4,666,141	1,544,870	
UNRWA	1,529,807	2,161,685	2,265,076	2,003,748	2,779,418	2,779,890	1,871,445	2,172,519		
Total Production	102,607,389	107,052,40	126,269,809	122,835,861	126,870,60	129,924,619	139,522,97	140,684,614	108,816,037	113,591,78

Table B.2 Analysis of the chemical elements of underground wells in the Gaza Strip 2015

<i>WELL ID</i>	<i>Coordinate X</i>	<i>Coordinate Y</i>	<i>Sector</i>	<i>TDS (mg/L)</i>	<i>Calcium Ca (mg/L)</i>	<i>Magnesium Mg (mg/L)</i>	<i>Sodium Na (mg/L)</i>	<i>Potassium K (mg/L)</i>	<i>Chloride CL(mg/L)</i>	<i>Nitrate NO₃ (mg/L)</i>	<i>Hardness</i>
Ad-Allh Azam	101733.00	107653.00	central	3621	183	194	800	8	1399	115	1255
Aesha pent alsedec	89463.17	92752.19	central	2821	97	79	710	6	1033	50	567
Al - Aqsa	85150.00	83400.00	central	2957	133	165	690	7	1112	122	1012
Al - cazan alswede	89463.17	92752.19	central	3918	199	179	940	7	1571	91	1235
Al - cazan alardy	93108.00	92454.00	central	2244	155	102	520	8	717	294	807
Al - mawase	92675.57	91699.97	central	2232	90	67	570	5	889	36	502
Al - ostaz al Reyade	91984.93	91891.39	central	2226	110	73	520	5	875	68	577
Al - sataer algaded	93117.84	91923.24	central	2455	104	80	660	6	990	38	587
Al - shoot	91850.00	92816.50	central	2678	124	113	710	9	1018	130	774
Al - soode	91200.34	90460.38	Gaza	1910	83	50	460	9	645	171	415
Al - zawayda algaded	99287.49	101643.34	Gaza	1420	123	77	245	10.1	430	186	625
Al sataer algaded 1	98441.98	104037.25	Gaza	2201	125	109	470	33	572	231	761
Dhaer	99330.04	105052.34	Gaza	1848	36	41	470	3	645	77	259
Eben- taylor	99164.44	104391.10	Gaza	4910	349	221	960	7	2500	84	1781

WELL ID	Coordinate X	Coordinate Y	Sector	TDS (mg/L)	Calcium Ca (mg/L)	Magnesium Mg (mg/L)	Sodium Na (mg/L)	Potassium K (mg/L)	Chloride CL(mg/L)	Nitrate NO₃ (mg/L)	Hardness
El Darag-2	98357.00	103676.00	Gaza	1978	111	110	400	6	617	299	731
El Naja	99285.00	99749.00	Gaza	2788	81	106	680	5	1159	60	641
El Tofah-1	99677.00	104755.00	Gaza	2393	238	132	340	4	1130	83	1140
EV 1	100834.75	105466.00	Gaza	1220	159	70	120	3.6	452	117	686
Heraa	101439.92	105833.23	Gaza	686	113	41	45	5.7	129	143	451
Kaled pen alwaled	101458.02	106192.92	Gaza	614	95	34	60	6	100	136	378
New Sorany	101739.29	106462.44	Gaza	637	110	41	40	5	93	166	441
Rimal-2	100513.58	105179.34	Gaza	1197	137	69	130	5	416	129	627
Said Syam	99330.04	105052.34	Gaza	9071	627	381	2000	7	4673	26	3137
Sheijaia-7	100155.89	104669.76	Gaza	1922	155	107	310	4	855	67	830
Sheikh Rodwan17	96899.00	98861.00	Gaza	2858	103	138	690	5	1097	114	828
TRC1	102220.49	103529.96	Gaza	955	53	47	160	3	290	67	327
TRC2	96532.49	102589.65	Gaza	11148	589	527	2500	88	5917	137	3643
W1	97636.71	104909.35	Gaza	15252	415	537	4250	75	8069	122	3249
W2	98727.34	104412.61	Gaza	6969	652	351	1200	12	3514	137	3076
W3	98867.20	104589.20	Gaza	5022	523	248	800	9	2427	153	2328
yaffa	98638.31	104989.89	Gaza	1488	137	89	315	6	588	136	708
A/180	99165.91	103952.40	Gaza	5084	256	223	1100	13	2521	105	1558
A/185	99054.74	103667.97	Gaza	1934	94	85	440	13	630	86	585
A/205	99049.89	103698.78	Gaza	1748	76	69	410	4	609	126	472
A/229	98480.54	104045.33	Gaza	1027	469	511	2400	23	5398	63	3279

WELL ID	Coordinate X	Coordinate Y	Sector	TDS (mg/L)	Calcium Ca (mg/L)	Magnesium Mg (mg/L)	Sodium Na (mg/L)	Potassium K (mg/L)	Chloride CL(mg/L)	Nitrate NO₃ (mg/L)	Hardness
A/231	98480.54	104045.33	Gaza	14818	481	658	4100	75	7925	96	3916
Abo Rashawn	96542.39	102055.46	Gaza	1631	79	51	380	4	574	86	407
C/127	95800.00	101100.00	Gaza	9312	274	389	2300	15	4734	52	2287
C/128	100758.48	102581.36	Gaza	1965	58	68	440	16	609	139	424
C/137	100778.72	102527.20	Gaza	2213	112	114	380	64	630	275	747
C/155	100758.48	102581.36	Gaza	2486	74	94	580	10	898	153	572
C/167	100819.87	102495.86	Gaza	2232	32	50	660	4	855	53	286
C/20	96200.00	99800.00	Gaza	1631	91	89	330	6	531	65	595
C/52	96236.51	101529.00	Gaza	1724	54	66	410	3.4	624	54	405
C/76	95800.00	101100.00	Gaza	1012	90	45	170	2	316	103	409
C/79a	96630.00	101300.00	Gaza	1339	75	67	240	3.6	445	97	463
D/2	97800.00	105000.00	Gaza	13950	614	480	3750	94.5	7423	169	3512
D/60/1	97780.00	104200.00	Gaza	19406	714	761	5300	45	10937	98	4918
D/67	97547.63	100274.63	Gaza	2449	82	102	620	8	868	117	627
D/69	97075.52	101805.57	Gaza	1643	123	56	325	4.6	574	144	538
D/70	97602.38	101510.21	Gaza	1693	137	94	240	6.8	495	218	731
D/71	98262.82	101598.40	Gaza	1457	119	77	270	7.7	495	146	613
D/72	99686.73	99202.55	Gaza	2970	40	76	860	4	1174	37	413
D/73	99287.49	101643.34	Gaza	2982	120	100	710	84	990	195	712
D/74	97533.92	103022.31	Gaza	1748	171	86	310	23	681	175	781
D/75	99462.72	103828.85	Gaza	1699	414	68	325	25	413	328	631

WELL ID	Coordinate X	Coordinate Y	Sector	TDS (mg/L)	Calcium Ca (mg/L)	Magnesium Mg (mg/L)	Sodium Na (mg/L)	Potassium K (mg/L)	Chloride CL(mg/L)	Nitrate NO ₃ (mg/L)	Hardness
D/77	97763.00	103474.00	Gaza	13330	726	571	3500	7	7209	59	4169
D/84	98047.00	104033.00	Gaza	2610	158	128	560	11	1116	104	921
D/86	96880.00	102930.00	Gaza	15996	639	649	3900	144	8535	120	4271
E/11A	97740.00	100510.00	Gaza	2480	100	104	600	17	861	160	678
E/11B	96150.00	102310.00	Gaza	12381	340	498	3100	24.8	6491	58	2904
E/11C	98013.00	100147.00	Gaza	3943	149	234	870	6.6	1685	116	1336
E/142A	95427.00	101265.00	Gaza	2796	124	112	620	3.7	1212	38	769
E/154	97021.00	103316.00	Gaza	18600	647	713	5000	74	10220	103	4554
E/156	98357.00	103676.00	Gaza	1575	127	84	310	8	543	148	662
E/157	101142.00	101394.00	Gaza	2207	39	49	600	3	811	59	298
E/168	101822.00	101636.00	Gaza	1451	129	66	245	17	502	162	597
E/171	97396.00	102871.00	Gaza	1680	137	68	300	33	581	152	623
E/177	98772.00	104116.00	Gaza	1693	114	101	320	3.4	552	227	701
E/90	100896.50	101702.60	Gaza	1862	94	93	360	4	710	185	619
F/225	100896.50	101702.60	Gaza	2015	71	72	470	3	753	108	472
H/95	100661.23	101542.90	Gaza	2486	48	72	700	4	985	113	414
L/127	100417.20	101298.90	Gaza	2455	45	62	680	4	949	132	367
L/176	102530.02	106252.34	Khan yones	1054	125	44	145	4	287	179	494
L/189A	102458.90	107032.67	Khan yones	687	76	38	97	4	201	113	346
L/214	82983.60	84477.57	Khan	3181	82	70	1000	13	1255	282	494

WELL ID	Coordinate X	Coordinate Y	Sector	TDS (mg/L)	Calcium Ca (mg/L)	Magnesium Mg (mg/L)	Sodium Na (mg/L)	Potassium K (mg/L)	Chloride CL(mg/L)	Nitrate NO₃ (mg/L)	Hardness
L/221	80946.91	81867.06	Khan yones	872	68	70	120	4	179	288	457
L/223	103013.33	105334.28	Khan yones	662	61	52	59	4	122	201	364
L/224	100661.23	101542.90	Khan yones	1662	79	59	400	3.7	610	123	439
L/226	81950.00	82385.47	Khan yones	4669	196	136	1405	10	1793	194	982
L/43	82848.90	83935.06	Khan yones	2226	133	102	540	5	753	339	753
L/87	82189.69	83279.19	Khan yones	2455	90	79	690	6	994	82	551
P/124	81831.60	82689.60	Khan yones	6653	311	258	1825	12	2848	239	1842
P/138	82517.76	81364.55	Khan yones	1668	58	44	465	4.2	619	77	326
P/144A	81695.85	83059.37	Khan yones	2623	86	78	760	6.3	1071	48	538
P/145	81564.96	82409.85	Khan yones	748	75	40	130	4	201	147	352
P/15	83062.91	83461.37	Khan yones	3019	154	139	780	9.4	997	376	955
P/153	83038.24	84202.84	Khan yones	2561	110	89	710	6.4	868	308	642
Q/68	99977.47	105276.26	North	806	104	60	73	2.3	143	163	506
Q/72	101838.00	104844.00	North	1575	155	92	245	9.8	416	262	769
Q/82	93879.91	98181.10	North	697	85	60	53	2	136	144	459
R/113a	102458.90	107032.67	North	898	123	61	85	2.3	230	109	557
R/161	102530.02	106252.34	North	887	110	61	85	6	215	92	528

WELL ID	Coordinate X	Coordinate Y	Sector	TDS (mg/L)	Calcium Ca (mg/L)	Magnesium Mg (mg/L)	Sodium Na (mg/L)	Potassium K (mg/L)	Chloride CL(mg/L)	Nitrate NO₃ (mg/L)	Hardness
R/308	99977.47	105276.26	North	5933	398	254	1350	7	3105	78	2044
R/309	102066.85	104589.41	North	776	62	57	108	3	179	127	389
R/311	102870.00	104470.00	North	763	72	48	108	3.2	208	79	378
R/313	101060.00	103930.00	North	1256	127	80	160	2.3	308	250	648
R/315	102466.60	104393.52	North	773	61	56	115	4.5	201	86	385
R/316	101277.88	104582.72	North	1141	137	78	120	14.4	251	257	662
R/317	102530.00	103915.00	North	861	58	48	153	4.7	244	50	344
R/338	103028.00	104016.00	North	950	67	56	160	6.5	280	70	401
R/342	102365.00	103029.00	North	1182	58	62	215	7.4	330	85	401
R/343	101795.00	103409.00	North	1116	65	60	200	4	323	80	409
R/344	100503.67	106104.13	Rafah	2034	125	136	385	10	839	114	870
R/345	103028.00	104016.00	Rafah	2096	123	127	385	11	861	97	380
R/347	101080.00	105220.00	Rafah	3137	95	92	850	6	1017	365	617
R/348	100503.67	106104.13	Rafah	2697	105	484	660	16	1220	47	611
R/349	102500.00	105600.00	Rafah	3249	154	113	780	8	1234	132	850
R/350	102164.82	105095.03	Rafah	3850	66	67	1080	5	1298	63	442
R/351	78701.00	80553.00	Rafah	322	29	16	55	2	65	62	138
R/352	78255.00	81207.00	Rafah	732	25	23	175	3	237	32	156
R/353	101795.00	103409.00	Rafah	4613	309	220	870	27	2159	56	1678
R/354	101379.33	105027.60	Rafah	5078	393	323	800	27	2482	38	3215
R/66b	102365.00	103029.00	Rafah	2852	230	145	410	9	1320	47	1174
R/66b	82424.00	81035.00	Rafah	2362	231	63	730	3.4	859	152	82
R/74	82517.76	81364.55	Rafah	2635	411	87	690	4	958	134	113

WELL ID	Coordinate X	Coordinate Y	Sector	TDS (mg/L)	Calcium Ca (mg/L)	Magnesium Mg (mg/L)	Sodium Na (mg/L)	Potassium K (mg/L)	Chloride CL(mg/L)	Nitrate NO₃ (mg/L)	Hardness
R/75	77598.02	79413.99	Rafah	1606	86	75	320	16	595	103	526
S/64	78772.70	79764.80	Rafah	2170	125	96	420	5	789	227	708
S/71	78320.00	80350.00	Rafah	1232	42	39	305	4	488	53	267
S/80	79368.62	79856.37	Rafah	2288	117	61	520	5	839	225	542
S/82	77926.76	78904.24	Rafah	2065	104	86	440	11	710	187	615
S/90	77736.61	80521.12	Rafah	587	35	24	115	3	186	103	185

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