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إدارة مصادر المياه في قطاع الزراعة بمنطقة خان يونس باستخدام طرق النمذجة

MANAGEMENT OF WATER RESOURCES FOR AGRICULTURE SECTOR AT KHANYOUNIS GOVERNORATE USING MODDELING APPROACHES

Prepared by :

Nooriddeen H. Adwan

Supervised by :

Dr. Yunes K. Mogheir

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إقـــرار

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Management of Water Resources for Agriculture Sector at Khanyounis Governorate Using Moddeling Approaches

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Signature:
Date:2/7/2014

اسم الطالب: نور الدين حسن محمد عدوان
التوقيع:
التاريخ:2/7/2014

بسم الله الرحمن الرحيم

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وبعد المناقشة التي تمت اليوم الأحد 17 شعبان 1435هـ، الموافق 2014/06/15م الساعة الحادية عشرة صباحاً، اجتمعت لجنة الحكم على الأطروحة والمكونة من:

د. يونس خليل المغير	**مشرفاً ورئيساً**	....
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واللجنة إذ تمنحه هذه الدرجة فإنها توصيه بتقوى الله ولزوم طاعته وأن يسخر علمه في خدمة دينه ووطنه.

والله ولي التوفيق ،،،

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أ.د. فؤاد علي العاجز

قال تعالى :

" وَأَنزَلْنَا مِنَ السَّمَاء مَاءً بِقَدَرٍ فَأَسْكَنَّاهُ فِي الأَرْضِ وَإِنَّا

عَلَى ذَهَابٍ بِهِ لَقَادِرُونَ" .

(المؤمنون / 18)

Abstract

Gaza Strip has an acute deficit in water both for domestic and agricultural use. This deficit is related to water quantity and quality. Agricultural sector is the main water consumer in the Gaza Strip with not less than 50% of the total groundwater extraction. The main aim of this research is to planning of agricultural practices based on the updated water deficit in terms of quantity and quality, in addition to incorporate the non-conventional water resources such as treated wastewater as a new agricultural water supply.

The ArcMap ArcGIS was used to find out and update the agricultural land in Khanyounis governorate through new aerial satellite image of 2012 year. Cropwat8.0 model was used to estimate the agricultural water consumption by utilizing the available information of land use, rainfall, and other meteorological data. The Water Evaluation and Planning System (WEAP) was used to simulate water demand and supply under different four scenarios in Khanyounis governorate till the year 2030 as follows: 1.Business as usual (Zero scenario), 2.Using Treated wastewater (TWW), 3.Changing crop pattern, 4.Combination scenario two and three.

The results showed that the area of existing agricultural land are 61,200 dunum. It was classified into four main categories: Orchards tress, Plastic green houses, Vegetables ,and Rain-fed crops. The total annual crop water requirement is calculated to be 24.2 MCM. The results of scenario 1 explained that the average water consumption for domestic and agricultural demands was doubled in reaching of year 2030. In the second scenario it is found that it can save 7.90 MCM annually when start plant operations in the year 2030 and save 16.40 MCM annually in the 2nd stage from the of the operation of TWWP in the year 2025. The results of the three options of scenario 3 explained the possibility of saving 1.35,6.06, and 8.76 MCM annually for the three option respectively. Scenario 4 results showed that it can save fresh water from groundwater aquifer 16.40 MCM annually without any changing in crop pattern while in the first option it can save 10.85 and 17.75 in the years 2018, 2025 respectively, in the second option saving quantities are reach to 15.56 and 22.46 in the years 2018 ,2025 respectively , finally in the third option the saved quantities reach to 18.26 and 25.16 MCM annually in years 2018, 2025 respectively.

The study concluded that the fourth scenario using TWW and changing crop pattern will enhance reducing stress on conventional water resources which might improve the groundwater availability in Gaza Strip.

ملخص

يعاني قطاع غزة من شح حاد في كميات المياه الزراعية والبلدية علاوة على تدهور جودة هذه المياه. يشكل الاستهلاك الزراعي في قطاع غزة النصيب الأكبر من المياه الجوفية المستخرجة بنسبة لا تقل عن 50% من هذه الكمية.

تهدف هذه الدراسة لتخطيط استخدام المياه في القطاع الزراعي بناءً على الميزانية المائية وشح المياه بالإضافة إلى تشجيع استخدام مصدر مياه غير تقليدي مثل إعادة استخدام المياه العادمة.

تم استخدام برنامج نظم المعلومات الجغرافية (ArcGIS, ArcMap) لتحديث الاستخدام الزراعي للأراضي في محافظة خانيونس عبر صورة جوية للعام 2012م، كما تم استخدام برنامج (Cropwat 8.0) لحساب الاستهلاك الزراعي للمياه بناءً على معلومات تتعلق باستخدام الأراضي والأمطار والبيانات المناخية. كذلك تم استخدام برنامج نظام تخطيط وتقييم المياه (WEAP) لمحاكاة الطلب على المياه وتوفيرها لأربعة سيناريوهات حتى العام 2030. وهذه السيناريوهات هي:1. الوضع القائم 2. استخدام المياه العادمة 3. تقييد نوع المحصول 4. الجمع بين السيناريو الثاني والثالث.

أظهرت النتائج أن مساحة الأرض الزراعية 61,200 دونم ومصنفة إلى أربع مجموعات: أشجار البساتين، الدفيئات الزراعية، الخضراوات، و المحاصيل البعلية. إن متطلبات المياه السنوية المحسوبة بلغت 24,2 مليون متر مكعب.

أظهرت نتائج السيناريو الأول أن متوسط استهلاك المياه للاستخدام البلدي والزراعي سيتضاعف بحلول العام 2030 بينما يمكن توفير 7,9 مليون متر مكعب سنوياً في حال تطبيق السيناريو الثاني وذلك عند بدء عملية الزراعة في العام 2030 علاوة على توفير 16,4 مليون متر مكعب سنوياً لخطة تشغيل محطة المعالجة في العام 2025 .

بينما نتائج الخيارات الثلاثة للسيناريو الثالث أظهرت إمكانية توفير 1,35، 6,06، 8,76 مليون متر مكعب سنوياً لهذه الخيارات على الترتيب. أظهرت نتائج السيناريو الرابع أنه يمكن توفير 16,4 مليون متر مكعب من المياه الجوفية سنوياً بدون تغيير النمط الزراعي بينما بتطبيق الخيار الأول يمكن توفير 10,85، 17,75 في السنوات 2018، 2025 على الترتيب. وفي حال تطبيق الخيار الثاني تصبح الكميات التي يمكن توفيرها 15,56، 22,46 مليون متر مكعب في السنوات 2018، 2025م على الترتيب. وأخيراً في حال تطبيق الخيار الثالث تصبح الكميات 18,26، 25,16 مليون متر مكعب في السنوات 2018، 2025 على الترتيب.

نتج عن الدراسة أن تطبيق السيناريو الرابع باستخدام المياه العادمة المعالجة وتقييد النمط الزراعي سيحسن من تخفيف الضغط على المصدر التقليدي للمياه وبالتالي سيحسن من توفر المياه الجوفية في قطاع غزة.

Dedication

This research is dedicated to:

*The memory of my **father**, may Allah grant him mercy…*

*My **mother** for her love, pray, and continuous sacrifices…*

*My beloved **wife** for her support and encouragement…*

To all of my brothers and sisters…

*To all of my **friends** and **colleagues**…*

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Table Of Content

1. Chapter (1) Introduction……………………………………………………………1
1.1 Background.. ……………………………………………………………………1
1.2 Problem Statement……………………………………………………………2
1.3 Objectives…………………………………………………………………………3
1.4 Why WEAP? ……………………………………………………………………3
1.5 Methodology ……………………………………………………………………4
1.6 Structure of the Thesis ……………………………………………………6
2. Chapter (2) Literature Review………………………………………………7
2.1 Introduction ……………………………………………………………………7
2.2 Integrated water resources management principles ………………7
2.3 Water Resources Management Modeling ……………………………8
2.3.1 Water Allocation Models ……………………………………………………8
2.4 Irrigation Water Quality ……………………………………………………10
2.4.1 Water Quality Problems ……………………………………………………10
2.5 Reference Evapotranspiration (ETo) ……………………………………13
2.5.1 Crop evapotrnspiration (ETc):……………………………………………14
2.5.2 Irrigation water requirements (IWR): ……………………………………15
2.6 CropWat Description and Concept: ………………………………………16
2.7 Wastewater reuse in agriculture ……………………………………………16
2.7.1 Wastewater reuse in Gaza Strip ……………………………………………17
2.8 Benefits and risks of wastewater reuse in agriculture …………………18
2.8.1 Benefits of wastewater reuse in agriculture ………………………………18
2.8.2 Risks of wastewater reuse in agriculture……………………………………19
2.9 Regulations and standards of treated wastewater: ………………………20

2.9.1 Treated wastewater reuse pilots (Gaza Strip) 20
2.9.2 Advantages of reclaimed water Use 21
2.9.3 WHO guidelines 22
2.9.4 Reclaimed water standards in the Mediterranean basin 22
2.9.5 Palestinian Standards & Regulation....25
2.10 Related studies: 27
2.11 Concluded Remarks 30

3. CHAPTER (3) Study Area 31

3.1 Introduction 31
3.2 Physical Settings 33
3.2.1 Climate 33
3.2.2 Temperature, Humidity and Solar Radiation 33
3.2.3 Rainfall 34
3.2.4 Reference Crop Evapotranspiration (ETo) 34
3.2.5 Topography and Soil 35
3.2.6 Land Use 36
3.3 Hydrogeology 37
3.3.1 Description of the Coastal Aquifer....37
3.4 Groundwater 38
3.4.1 Nitrate: 40
3.4.2 Chloride: 41
3.5 Current Status of Wastewater Treatment and Reuse 42
3.6 Current Status of Wastewater Treatment and Reuse in Gaza Strip 42
3.7 Khanyounis Wastewater & Treatment Plant (KY WWTP) 45
3.7.1 Background and Previous Considerations 45

3.7.2 Process Design Criteria and Considerations 46

3.7.3 Implementation Phases 46

3.7.4 Infiltration Basins 47

3.8 Agricultural Water Demand 48

3.8.1 Gaza Strip Agricultural Water Demand 49

3.9 Agricultural Water Supply 50

3.9.1 Agrictural Wells in Khanyounis 51

3.9.2 Quality of Agricultural Water...53

3.10 Khanyounis Agricultural Practice 53

3.10.1 Cultivated Area 53

3.10.2 Crops 54

3.10.3 Field crops: 54

3.11 Irrigation methods: 57

4. CHAPTER (4) Methodology...59

4.1 Estimation of the Area of Agricultural land 59

4.1.1 Building the Geodatabase...59

4.1.2 Physical design of the database..60

4.1.3 Creating and Editing Shape file 60

4.1.4 Auditing and verification 61

4.1.5 Calculation of Agricultural area 62

4.1.6 Distribution of Agricultural crops 63

4.2 Crop Water Requirements 67

4.2.1 Leaching requirements 68

4.4 WEAP Development 70

4.5 The WEAP Approach 71

4.6 Model Structure 71

4.7 Modeling Process of WEAP 72

4.8 Scenarios Development 75

4.8.1 Business As Usual (Zero Scenario) 76

4.8.2 Using Treated Wastewater 77

4.8.3 Changing Crop Pattern Scenario 78

4.8.4 Combination Scenario 2 & 3 79

5. CHAPTER(5) Results & Discussion...80

5.1 Scenario Analysis and Results 80

5.1.1 Results of Scenario 1 80

5.1.2 Results of Scenario 2 82

5.1.3 Results of Scenario 3 85

5.1.4 Results of Scenario 4 89

5.2 Comparison of Scenarios 90

5.2.1 Ground Water Storage..90

5.2.2 Water Balance 90

6. CHAPTER(6) Conclusions & Recommendations.....................................92

6.1 Conclusions 92

6.2 Recommendations 94

References...95

List of Figures

Figure 1.1 Methodology flow chart 5

Figure 2.1: Reference (ETo), crop evapotranspiration under standard (ETc) and nonstandard conditions (ETc adj). Source: (FAO, 1998) 15

Figure 3.1: Map of Gaza Strip 31

Figure 3.2:Khanyounis Governorate map((prepared by researcher) 32

Figure 3.3: Mean monthly maximum, minimum and average temperature (C°) for the Gaza Strip (period 1999 – 2005)...33

Figure 3.4: Locations of rain stations in the Gaza Strip (PWA, 2000) 35

Figure 3.5: Soil Classifications in Khanyounis Governorate (MOPIC, 2004) 36

Figure 3.6: Location map of Khanyounis Governorate (MoP, 2005) 37

Figure 3.7: Generalized Cross Section of the Coastal Plain, (Dan. Greitzer,1967) 38

Figure 3.8: Average groundwater table levels in Khanyounis Governorate for year 2007. 39

Figure 3.9: Average nitrate concentrations in groundwater in Khanyounis Governorate for year 2007 40

Figure 3.10: Average chloride concentrations in groundwater in Khanyounis governorate for year 2007. 41

Figure 3.11 : Existing and Planned Wastewater Plants in the Gaza Strip (PWA ,2011) 43

Table 3.12 : Treated wastewater requirement of the plant 46

Figure 3.13 Recent photo for Khuza'a (Al Fukhari) infiltration area 48

Figure 3.14 : development of water consumption over the years 1992 to 2011 (PWA , 2013) 51

Figure 3.15 Agricultural wells at Khanyounis governorate 52

Figure 4.1 : Aerial Satellite image a) Horticultural crops, b) Vegetables, c)Green houses & d)Rain fed crops. 61

Figure 4.2 General view for Abu Teama Agricultural land illustrating the type cultivated crops..62

Figure 4.3 Agricultural crops at Khanyounis governorate 63

Figure 4.4 Output of GIS map satellite image with different agricultural crops at Khanyounis governorate (prepared by the researcher) 64

Figure 4.5 Distribution of Vegetables through Khanyounis governorate (prepared by the researcher)..65

Figure 4.6 Distribution of field crops through Khanyounis governorate (prepared by the researcher)..65

4.7 Distribution of orchards through Khanyounis governorate (prepared by the researcher) 66

Figure 4.8 Distribution of greenhouses through Khanyounis governorate (prepared by the researcher)..66

Figure 4.9 Schematic view of WEAP model showing the various nodes. 72

Figure 4.10 Study area represented in WEAP..73

Figure 4.11: Annual water requirement for population growth in Khanyounis governorate..74

Figure 4.12 : Three main categories' of Agricultural land in Khanyounis governorate 74

Figure 4.13: Type of tress and CWR for each type 75

Figure 4.14 Annual water requirement for projecting agricultural demand in Khanyounis governorate..75

Figure 5.1: Domestic and agricultural demand for Khanyonuis governorate up to 2030 under Scenario 1. 80

Figure 5.2: Ground water storage up to 2030 under Sc.1. 82

Figure 5.3 WEAP screen input of infiltration basin at 2018 – 2025............................83

Figure 5.4 Influence of ground water storage after treated waste water (Sc.2) using WEAP..84

Figure 5.5 Comprasion between scenario No.1 & scenario No.2 for ground water storage 84

Figure 5.6: Domestic and agricultural demand for Khanyonuis governorate up to 2030 under Sc.2. 88

Figure 5.7 WEAP results for comparison between 3 option of scenario changing crop pattern 88

Figure 5.8 WEAP results for comparison between 4 Scenarios..................................90

List of Tables

Table 2.1 Typical salts found in irrigation water 11

Table 2.2 Quality Criteria of Irrigation with Reclaimed Water in Cyprus 23

Table 2.3: Reclaimed Water Use Criteria in Israel 24

Table 2.4 Tunisian Standards of Reclaimed Water Use 25

Table 2.5: Palestinian Standards for Irrigation and Recharge 26

Table 3.1 : Average yearly precipitation in Khanyounis governorate from 1999-2012 (source: MoA, 2013) 34

Table 3.2: General features of wastewater production and collection in Gaza Strip (PWA , 2011). 44

Table 3.3: Annual potential of wastewater generation in GS, (Afifi, 2006) 45

Table 3.4: The incoming flows for KY WWTP 47

Table 3.5: The design loads for KY WWTP. 47

Table 3.6 Infiltration rates and hydraulic loads for Al Fukhari site. 48

Table 3.7: Irrigation area due to cultivated area in Gaza Stip (MoA ,2010) 49

Table 3.8: Agricultural Water Consumption for the year 2010/2011 at Khanyounis Governorate (MoA ,2011) 50

Table 3.9 : development of agricultural land over the years 2002 to 2011 (PWA , 2013) 52

Table 3.10: Cultivated land at Khanyounis Municipalities and other area 54

Table 3.11: Area of Field Crops and types in Khanyounis Governorate (MoA , 2012) 54

Table 3.12: Area of Horticultural Crops and types in Khanyounis governorate (MoA , 2012) 55

Table 3.13: Area of Vegetables Crops and types at Khanyounis Governorate (MoA , 2012) 56

Table 3.14: Area of Vegetables Medical and flowers and types at Khanyounis Governorate (MoA , 2012) 57

Table 4.1: estimated area for cultivated land for Khanyounis governorate from Raster image 62

Table 4.2 Monthly crops water requirements (mm) using Cropwat model 67

Table 4.3 Leaching requirement (ratio, %) 68

Table 4.4 Gross irrigation water demand for the proposed calculated crops. 69

Table 4.5: Treated wastewater quality requirement of the plant 78

Table 4.6 Scenario 2 , with 3 option of changing crop pattern 79

Table 5.1 Water balance for scenario No.1 81

Table 5.2 :Results of scenario No.2 using treated wastewater in agricultural irrigation 82

Table 5.3 Recommended guidelines for agricultural reuse of wastewater 85

Table 5.4 Option I for changing crop pattern under Sc.3 85

Table 5.5 Option II for scenario changing crop pattern 86

Table 5.6 Option III for scenario changing crop pattern 86

Table 5.7 Total irrigation demand for three option 87

Table 5.8 Combination of scenario No.2 & Scenario No.3 results 89

Table 5.9 Water balance for the four scenario till the year 2030 91

LIST OF ABBREVIATIONS & ACRONYMS

AMSL	Above mean sea level
CWR	Crop water requirement
dS/m	deciSiemens per metre
EC	Electrical Conductivity
EC_e	Average soil salinity tolerated by the crop
EC_w	Salinity of the applied irrigation water in dS/m.
ET	Evapotranspiration
ETo	Reference evapotranspiration (mm day -1)
FAO	Food and Agriculture Organization
IWR	Irrigation water requirement
Kc	Crop coefficient
MCM	Million cubic meter
MCM	Million cubic meter
MoA	Ministry of Agriculture
mS/cm.	milliSiemens (mS) per centimetre
MSL	Mean sea level
$_{o}$C	Celsius temperature scale
P	Precipitation
PAPP	Programme of Assistance to the Palestinian People
PCBS	Palestinian Central Bureau of Statistics
PWA	Palestinian Water Authority
R.H	Relative humidity (%)
T	Temperature (°C)
T_{max}	Maximum temperature (°C)
T_{min}	Minimum temperature (°C)
UNDP	United Nations Development Programme
WFP	World Food Program
FAO	Food & Agricultural Organization

Chapter

1

Introduction

1.1 *Background*

Water is a vital component of agricultural production. It is essential to maximize both yield and quality. Water has to be applied in the right amounts at the right time in order to achieve the right crop result at the same time. The application of water should avoid waste of a valuable resource and be in sympathy with the environment as a whole (SAI, 2010). Water scarcity in Palestine generally and in Gaza Strip especially is characterized by challenges of both an environmental and human-made nature. Declining levels of water access resulting from the combined effects of drought, dropping water tables and seawater intrusion have greatly impacted Palestinian water use. The availability of water at an acceptable and consistent level is a prerequisite for building sustainable and resilient livelihoods.

Gaza Strip is one of the semi-arid area where rainfall is falling in the winter season from September to April, the rate of rainfall is varying in the Gaza Strip and ranges between 200mm/year in the south to about 400mm/year in the north, while the long term average rainfall rate in all over the Gaza Strip is about 317mm/year (CMWU, 2010).

Population growth, climate change, and agricultural and industrial development continue to increase pressure on the existing groundwater resources, the only current source of fresh water in Gaza. Groundwater provides the potable water supply for the human consumption and crops irrigation (Afifi, 2006)

The agricultural area is approximately 1.854 million dunum, or 31% of the total area of Palestinian land, including 91% in the West Bank and 9% in the Gaza Strip (MOA, 2009).

The agricultural sector in the Gaza Strip on an average consumes around 75-80 million cubic meters of water annually. All amounts of water used for this purpose come from groundwater wells, more than two thirds of the total cultivated areas are irrigated areas (118,216 dunum out of the total irrigated area of 154,821 dunums) (PWA, 2010).

For Palestinians, the water sector is not going to develop without understanding the current situation. Agriculture contributes to 12% of the GDP and about 117000 people are working in this sector (The World Bank, 2009). Hence, the economic situation will be significantly improved once both rain-fed and irrigated agriculture bloom.

For areas of deficient water balance, and generally in sight of a sustainable management of water resources, wastewater reclamation and reuse constitutes an increasing practice in recent years (Fereres & Soriano, 2007). Most countries in the Mediterranean and the Middle East have adopted a policy of recycling treated wastewater for other uses, principally agriculture, provided that the effluent is chemically and microbiologically suitable, and conforms to quality standards (CAMP, 2000).

1.2 Problem Statement

Gaza Strip suffers from a disastrous situation due to the poor water quality and with the Coastal Aquifer as the sole water source shared with Israel. The aquifer is being over pumped with annual quantities that are double that of the safe pumping rate (50-60 MCM/year); this leads to seawater and surrounding saline aquifers intruding into this fresh water source causing salination (PWA,2012). It is forecasted that the Palestinian territories are facing a severe water deficit likely to be exacerbated within the next years due to the consequence of the global warming and excessive use of irrigation water (Ashour & Al-Najar, 2012). The agriculture sector is the second major consumer of groundwater in the Gaza Strip, where the level of groundwater, the main water resource, is being depleted and its quality is adversely affected. Urban use of land and water will also increase enormously. The amount of fresh water allocated for agriculture will be reduced radically to meet the increasing demand for the municipal purposes.

As a result of all current and expected problems, there is an urgent need to adopt solutions to achieve conservation of water quantity, improve water quality, and achieve sustainability.

1.3 Objectives

The main aim of this research is to ***Re-planning of agricultural practices based on the updated water deficit in terms of quantity and quality , in addition to incorporate the non-conventional water resources such as treated wastewater as a new agricultural water supply. Khanyounis governorate will be used as a case study***.

To be more specific, the objectives of this research are:

- ✓ To determine the water supply and demand for cultivated lands in Khanyounis governorate for agricultural purpose.
- ✓ To determine the needed quality and quantity of treated wastewater required for some specified trees and crops in cultivated lands.
- ✓ Determine the type of trees and crops which could irrigated by treated wastewater matching to Strategic plan for Ministry of Agriculture.
- ✓ To suggest a new plan for agricultural practice with a map display new arrangement of agricultural crops distributed among all governorates based on conventional and non-conventional resources for irrigation.
- ✓ Modeling water allocation in Khanyounis governorate using (WEAP) to simulate water demand and supply under different four scenarios in Khanyounis governorate.

1.4 Why WEAP?

For our study we selected the Water Evaluation and Planning (WEAP) software. WEAP is particularly suitable for the intended research objective because it incorporates a demand priority and supply preference approach to describe water resource operating rules that function as system demands driving the allocation of water from surface and groundwater supplies to the demand centers (Yates et al. 2005). WEAP can be integrated with groundwater models and water quality data and is easily extendable to other sub-catchments and larger areas. Furthermore, WEAP's data structure maps the information in spatial and temporal dimensions. The development of its structural equations allows a statistical evaluation while its visual mode provides a practical interface for decision making processes by policy makers and stakeholders alike. Concerning output, WEAP simulates various water management scenarios to evaluate the impact on water availability and water quality for different client groups in a spatially explicit manner.

1.5 Methodology

It is intended to achieve the objectives of the study by the following steps Figure 1.1:

- **Literature review**

  Revision of accessible references as books, studies and researches relative to the topic of this research which may include water resources management, agriculture water demand, water situation in Gaza Strip.

- **Data collection**

  Data gathering from relevant institution or organizations involved in agriculture or related environmental activities and ministries that includes details and time series data about different influenced parameters.

- **Modeling & Tools**

  1. **Agricultural water demand :** Modeling the available data (temperature, humidity, rainfall, sunshine hours, and wind speed) using CropWat 8.0 Windows, which is a program that estimate irrigation water requirements.
  2. **Land use** : ArcGIS Application was used as supporting tools for map analysis and measurements that measured the buildup area, open area and agricultural areas according to the updated satellite images .
  3. **WEAP** : The Water Evaluation and Planning System (WEAP) was used to simulate water demand and supply under four different scenarios in Khanyounis governorate

- **Thorough analysis** :

  in order to estimate demand water of agriculture a thorough analysis was used to find the water requirements of each crop was performed. The analysis was based on the evapotranspiration value (ETc), which included two different processes: the volume of water evaporated from soil as well as that used by vegetation.

- **Management Scenarios** :

  Develop future management scenarios related to the population growth, supply and demand changes, socio-economic factors, political agreements and the use of non-conventional water resources.

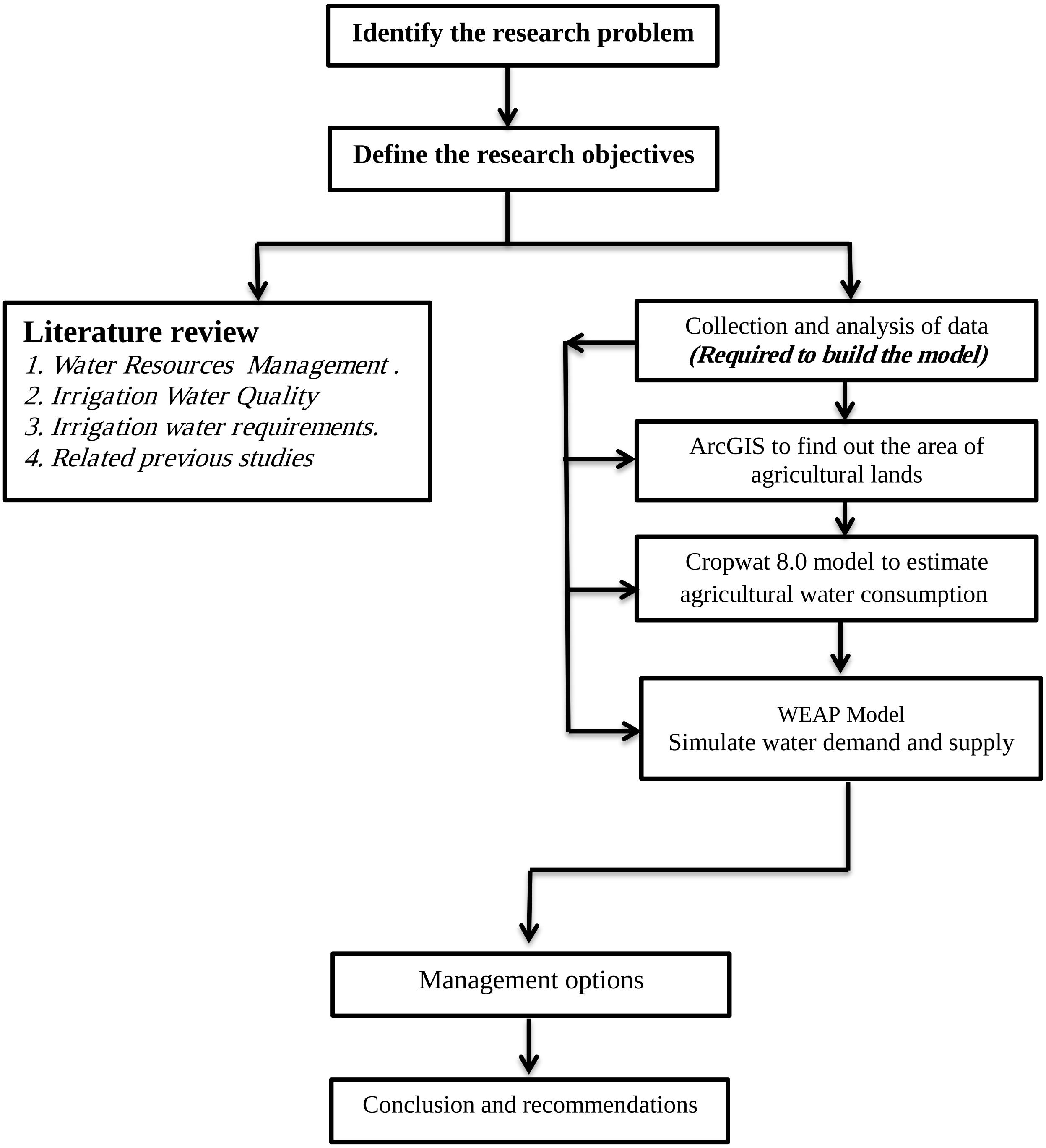

Figure 2.1 Methodology flow chart

1.6 Structure of the Thesis:

The basic structure of the thesis is organized in six chapters, as follows:

- **Chapter One: "Introduction"**

It provides a background on Agricultural water crisis, summary on the problem statement, research objectives and structure of the research.

- **Chapter Two: "Literature Reviews"**

It summarizes the literature reviews along with background information related to Water management ,Irrigation water quality , Reference evapotranspiration .

- **Chapter Three: "Study Area"**

It describes the study area geographically with briefing about its Agricultural practice at Khanyounis area , properties of supply water , historical metrological data analysis.

- **Chapter Four: "Methodology"**

This chapter to find out the estimated area of cultivated land using GIS, computing the crop water requirements, Modeling water allocation in Khanyounis governorate. Simulations of water supply and demand in Khanyounis governorate are used to evaluate the features and benefits of treated wastewater in relation to agricultural practice.

- **Chapter Five: "Results and Discussions"**

Discuss the four scenario's for managing agricultural water during up to 2030, and find the best scenario to be applied.

- **Chapter Six: "Conclusion and Recommendations"**

It provides a brief summary on research findings as a conclusion, followed by future recommendations on the best practices.

CHAPTER

2

Literature Review

2.1 Introduction

Many regions are facing formidable freshwater management challenges. Allocation of limited water resources, environmental quality, and policies for sustainable water use are issues of increasing concern (SEI, 2008). How to assess the impacts of water resources management on alleviating the water shortage is the key to take measures further. The benefits of water management, however, can be difficult to quantify (Benchea et al., 2011; Iliadis et al., 2010; Miller, 2006). In the near future, availability of water rather than land will be the main constraint to agricultural development of arid and semi-arid countries of the Mediterranean. There is no doubt that, without an efficient control and proper water management, self-sufficiency in food and energy will continue to be a mirage for most countries of the region (Hamdy, 2001).

The water situation in the Gaza Strip deteriorating significantly over the past years, whether in terms of quantity or quality, for many reasons including; increased demand for water, and dependence on intensive agriculture due to the lack of agricultural land in the Gaza Strip, in addition to a sharp deterioration in water quality with the large increase in the number of agricultural wells and overdraft of the aquifer, and the annual increase in population. This chapter discusses the studies on water management in the agriculture sector .

2.2 Integrated water resources management principles

Integrated Water Resources Management (IWRM) is defined as “a process that strives to balance regional economic growth while achieving wise environmental stewardship” by encouraging the participation of seemingly disparate interests

(Bourget, 2006). IWRM helps to protect the world's environment, foster economic growth and sustainable agricultural development, promote democratic participation in governance, and improve human health . Integrated Water Resources Management is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystem (Amani, 2004).

2.3 Water Resources Management Modeling

Modeling of water conditions in a given area is a simplified description of the real system to assist calculations and predictions used to estimate the amount of water that is needed to meet the existing and projected demands under potential availability and demand scenarios, and determine what interventions are necessary, as well as when and where, and their cost. Models can represent the important interdependencies and interactions among the various control structures and users of a water system; in addition they can help identify the decisions that best meet any particular objective and assumptions (Loucks, et al., 2005).

The two principal approaches to modeling are simulation of water resources behavior based on a set of rules governing water allocations and infrastructure operation; and optimization of allocations based on an objective function and accompanying constraints. Simulation models address what if questions. Their input data define the components of the water system and their configuration and the resulting outputs can identify the variations of multiple system performance indicator values. Simulation works only when there are a relatively few alternatives to be evaluated. Optimization models are based on objective functions of unknown decision variables that are to be maximized or minimized. The constraints of the model contain decision variables that are unknown and parameters whose values are assumed known. Constraints are expressed as equations and inequalities (Loucks, et al., 2005).

2.3.1 Water Allocation Models

For water allocation different models are used such as :

2.3.1.1 WEAP

The Water Evaluation and Planning System (WEAP) developed by the Stockholm Environment Institute's Boston Center (Tellus Institute) is a water balance software program that was designed to assist water management decision makers in evaluating water policies and developing sustainable water resource management plans. WEAP operates on basic principles of water balance accounting and links water supplies from rivers, reservoirs and aquifers with water demands, in an integrated system. Designed to be menu driven and user-friendly, WEAP is a policy-oriented software model that uses water balance accounting to simulate user constructed scenarios. The program is designed to assist water management decision makers through a user friendly menu-driven graphical user interface. WEAP can simulate issues including;

sectoral demand analyses, water conservation, water rights, allocation priorities, groundwater withdrawal and recharge, stream flow simulation, reservoir operations, hydropower generation, pollution tracking (fully mixed, limited decay), and project cost/benefit analyses. Groundwater supplies can be included in the WEAP model by specifying a storage capacity, a maximum withdrawal rate and the rate of recharge. Minimum monthly in stream flows can be specified (Raskin, et al., 1992).

2.3.1.2 Aquarius:

Aquarius is a temporal and spatial allocation model for managing water among competing uses. The model is driven by economic efficiency which requires the reallocation of all flows until the net marginal return of all water uses is equal. In the graphical user interface, the components are represented by icons, which can be dragged and dropped from the menu creating instances of the objects on the screen. These can be positioned anywhere on the screen or removed. Once components are placed on the screen, they are linked by river reaches and conveyance structures. The model does not include groundwater or water quality. The model could be used to evaluate net benefits by subtracting costs from benefits in the individual benefit functions. From the model documentation, it is apparent that making significant modifications to the model or its structure would be very difficult (Diaz et al., 1997).

2.3.1.3 CALSIM

The California Water Resources Simulation Model was developed by the California State Department of Water Resources .The model is used to simulate existing and potential water allocation and reservoir operating policies and constraints that balance water use among competing interests. Policies and priorities are implemented through the use of user-defined weights applied to the flows in the system. Simulation cycles at different temporal scales allow the successive implementation of constraints. The model can simulate the operation of relatively complex environmental requirements and various state and federal regulations (Quinn et al., 2004).

2.3.1.4 WaterWare

Is a decision support system based on linked simulation models that utilize data from an embedded GIS, monitoring data including real-time data acquisition, and an expert system. The system uses a multimedia user interface with Internet access, a hybrid GIS with hierarchical map layers, object databases, time series analysis, reporting functions, an embedded expert system for estimation, classification and impact assessment tasks, and a hypermedia help- and explain system. The system integrates the inputs and outputs for a rainfall-runoff model, an irrigation water demand estimation model, a water resources allocation model, a water quality model, and groundwater flows and pollution model (FEDRA, 2002).

2.3.1.5 OASIS

Operational Analysis and Simulation of Integrated Systems developed by Hydrologics, Inc. is a general purpose water simulation model. Simulation is accomplished by solving a linear optimization model subject to a set of goals and constraints for every time step within a planning period. OASIS uses an object-oriented graphical user interface to set up a model, similar to ModSim. A river basin is defined as a network of nodes and arcs using an object-oriented graphical user interface. Oasis uses Microsoft Access for static data storage, and HEC-DSS for time series data. The Operational Control Language (OCL) within the OASIS model allows the user to create rules that are used in the optimization and allows the exchange of data between OASIS and external modules while OASIS is running. OASIS does not handle groundwater or water quality, but external modules can be integrated into OASIS (Randall et al, 1997).

2.3.1.6 Aquatool

Aquatool consists of a series of modules integrated in a system in which a control unit allows the graphical definition of a system scheme, database control, utilization of modules and graphical analysis of results. Modules include: surface and groundwater flow simulation; single- and multi-objective optimization of water resources; hydrologic time series analysis; risk based WRS management. Water quality is not included in Aquatool model (Andreu, 2004).

2.4 Irrigation Water Quality

In several arid regions in the world crop cultivation mainly depends on groundwater supply for irrigation. The irrigation water consist of different concentrations of dissolved salts and many of problems around the world are directly resulted from the cumulative salts in the soil where the irrigation water is the source of these salts. As a result, there is no set limit on water quality; rather, its suitability for use is determined by the conditions of use which affect the accumulation of the water constituents and which may restrict crop yield (FAO, 1985)

2.4.1 Water Quality Problems

The soil problems most commonly encountered and used as a basis to evaluate water quality are those related to salinity, water infiltration rate, toxicity and a group of other miscellaneous problems.

2.4.1.1 Salinity

The terms salt and salinity are often used interchangeably, and sometimes incorrectly. A salt is simply an inorganic mineral that can dissolve in water. Many people associate salt with sodium chloride common table salt. In reality, the salts that affect both surface water and groundwater often are a combination of sodium, calcium, potassium, magnesium, chlorides, nitrates, sulfates, bicarbonates and carbonates as shown in Table 2.1 . (FAO, 1985). Salts in soil or water reduce water availability to the crop to such an extent that yield is affected.

2.4.1.2 Table 2.1 Typical salts found in irrigation water

Common Name	Chemical Name
Table salt	Sodium chloride
Glauberís salt	Sodium sulfate
Baking soda	Sodium bicarbonate
Epsom salt	Magnesium sulfate
Gypsum	Calcium sulfate
Street salt	Calcium chloride
Muriate of potash	Potassium chloride
Muriate of sulfate	Potassium sulfate

2.4.1.3 Water Infiltration Rate

An infiltration problem related to water quality occurs when the normal infiltration rate for the applied water or rainfall is appreciably reduced and water remains on the soil surface too long or infiltrates too slowly to supply the crop with sufficient water to maintain acceptable yields. Although the infiltration rate of water into soil varies widely and can be greatly influenced by the quality of the irrigation water, soil factors such as structure, degree of compaction, organic matter content and chemical make-up can also greatly influence the intake rate.

The two most common water quality factors which influence the normal infiltration rate are the salinity of the water (total quantity of salts in the water) and its sodium content relative to the calcium and magnesium content. A high salinity water will increase infiltration. A low salinity water or a water with a high sodium to calcium ratio will decrease infiltration. Both factors may operate at the same time. Secondary problems may also develop if irrigations must be prolonged for an extended period of time to achieve adequate infiltration. These include crusting of seedbeds, excessive weeds, nutritional disorders and drowning of the crop, rotting of seeds and poor crop stands in low-lying wet spots. One serious side effect of an infiltration problem is the potential to develop disease and vector (mosquito) problems (FAO, 1985)

2.4.1.4 Toxicity

Toxicity problems occur if certain constituents (ions) in the soil or water are taken up by the plant and accumulate to concentrations high enough to cause crop damage or reduced yields. The degree of damage depends on the uptake and the crop sensitivity. The permanent, perennial-type crops (tree crops) are the more sensitive. Damage often occurs at relatively low ion concentrations for sensitive crops. It is usually first evidenced by marginal leaf burn and interveinal chlorosis. If the accumulation is great enough, reduced yields result. The more tolerant annual crops are not sensitive at low concentrations but almost all crops will be damaged or killed if concentrations are sufficiently high.

The ions of primary concern are chloride, sodium and boron. Although toxicity problems may occur even when these ions are in low concentrations, toxicity often accompanies and complicates a salinity or water infiltration problem. Damage results when the potentially toxic ions are absorbed in significant amounts with the water taken up by the roots. The absorbed ions are transported to the leaves where they accumulate during transpiration. The ions accumulate to the greatest extent in the areas where the water loss is greatest, usually the leaf tips and leaf edges. Accumulation to toxic concentrations takes time and visual damage is often slow to be noticed. The degree of damage depends upon the duration of exposure, concentration by the toxic ion, crop sensitivity, and the volume of water transpired by the crop. In a hot climate or hot part of the year, accumulation is more rapid than if the same crop were grown in a cooler climate or cooler season when it might show little or no damage. (FAO, 1985)

Toxicity can also occur from direct absorption of the toxic ions through leaves wet by overhead sprinklers. Sodium and chloride are the primary ions absorbed through leaves, and toxicity to one or both can be a problem with certain sensitive crops such as citrus. As concentrations increase in the applied water, damage develops more rapidly and becomes progressively more severe.

2.4.1.5 Miscellaneous

Several other problems related to irrigation water quality occur with sufficient frequency for them to be specifically noted. These include high nitrogen concentrations in the water which supplies nitrogen to the crop and may cause excessive vegetative growth, lodging, and delayed crop maturity; unsightly deposits on fruit or leaves due to overhead sprinkler irrigation with high bicarbonate water, water containing gypsum, or water high in iron; and various abnormalities often associated with an unusual pH of the water. A special problem faced by some farmers practising irrigation is deterioration of equipment due to water-induced corrosion or encrustation. This problem is most serious for wells and pumps, but in some areas, a poor quality water may also damage irrigation equipment and canals. In areas where there is a potential risk from diseases such as malaria, schistosomiasis and lymphatic filariasis, disease vector problems must be considered along with other water quality-related problems. Vector problems (mosquitoes) often originate as a secondary trouble related to a low water infiltration rate, to the use of wastewater for irrigation, or to poor drainage. Suspended organic as well as inorganic sediments cause problems in irrigation systems through clogging of gates, sprinkler heads and drippers. They can cause damage to pumps if screens are not used to exclude them. More commonly, sediments tend to fill canals and ditches and cause costly dredging and maintenance problems. Sediment also tends to reduce further the water infiltration rate of an already slowly permeable soil. (FAO, 1985)

2.5 *Reference Evapotranspiration (ET∘):*

The combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration is referred by evapotranspiration (ET) (FAO, 1998). The evapotranspiration rate is normally expressed in millimeters (mm) per unit time. The rate is expressed as the amount of water lost from a cropped surface in units of water depth, the time unit can be an hour, day, month or even the entire growing period or year. The reference evapotranspiration (ETo) is defined as the evapotranspiration from a reference surface of a reference crop. FAO defined the reference crop as a hypothetical crop with an assumed height of 0.12m having the surface resistance of 70 sm−1 and albedo of 0.23, closely resembling the evaporation of an extension surface of green grass of uniform height which is actively growing and adequately watered. Thus, ETo is a climatic parameter expressing the evaporation power of the atmosphere and can be computed from meteorological data. CropWat uses the FAO Penman- Monteith method to calculate ETo; the method was recommended as the standard method for the definition and computation of the reference evapotranspiration. Equation 2.1 present the computation of ETo which is a result of an expert consultation held in May 1990 and organized by the FAO. (FAO, 1998)

$$ET_{\circ} = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \ldots\ldots\ldots\text{equation 2.1}$$

Where;

ETo Reference evapotranspiration [mm day-1]

R_n Net radiation at the crop surface [MJ m-2 day-1]

G Soil heat flux density [MJ m-2 day-1]

T Mean daily air temperature at 2 m height [°C]

u_2 Wind speed at 2 m height [m s-1]

e_s Saturation vapour pressure [kPa]

e_a Actuel vapour pressure [kPa]

$e_s - e_a$ Saturation vapour pressure deficit [kPa]

Δ Slope vapour pressure curve [kPa °C-1]

γ Psychrometric constant [kPa °C-1]

Equation 2.1 standard climatological records of solar radiation (sunshine), air temperature, humidity and wind speed. To ensure the integrity of computations, the weather measurements should be made at 2 m (or converted to that height) above a extensive surface of green grass, shading the ground and not short of water.

2.5.1 Crop evapotrnspiration (ET_c):

Crop evapotranspiration (ET_c) refers to the evapotranspiration from excellently managed, large, well-watered fields that achieve full production under the given climatic conditions (Equation 2.2). Due to sub-optimal crop management and environmental constraints that affect crop growth and limit evapotranspiration, ET_c under non-standard conditions generally requires a correction to obtain $ET_{c\ adj}$ (FAO, 1998), (Figure 2.1). For the purpose of this study $ET_{c\ adj}$ is not considered as the impact of climate change only; optimal management and environmental conditions should be maintained. Crop evapotranspiration can be determined using the equation 2.2 :

$$ET_c = K_c \times ET_o \dots\dots\dots \text{equation 2.2}$$

Where;

ET_o Rreference evapotranspiration,

K_c Crop coefficient.

At this stage, to calculate Kc using CropWat it is necessary to define the crop, select cropping pattern, determine time of planting or sowing, rate of crop development stage and growing period.

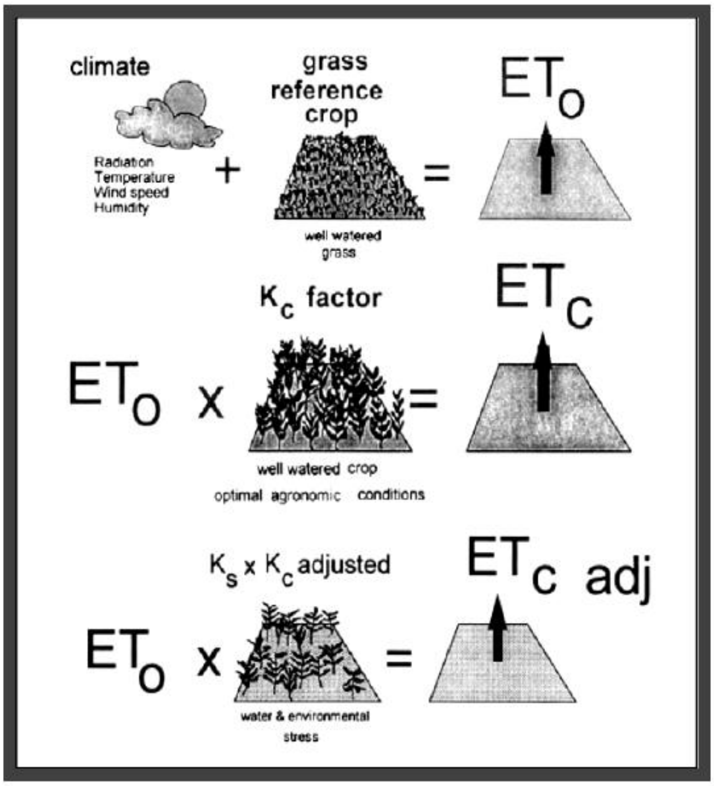

Figure 2.1: Reference (ETo), crop evapotranspiration under standard (ETc) and nonstandard conditions (ETc adj). Source: (FAO, 1998)

2.5.2 Irrigation water requirements (IWR):

The irrigation water requirement of a crop is the total amount of water that must be supplied by irrigation to a disease free crop, growing in a large field with adequate soil water and fertility, and achieving full production potential under the given growing environment (FAO, 1998).The irrigation water requirement (IWR) basically represents the difference between the crop water requirement and effective rain, where the effective rain is defined as the portion of the rainfall that is effectively used by the crop after rain. The amount of effective rainfall depends on the precipitation rate and soil moisture conditions.

2.5.3 Crop water requirement (CWR):

Under optimal management and environmental conditions crop evapotranspiration is equal to the crop water requirements. In other words, the amount of water required to compensate the evapotranspiration loss from the cropped field is defined as crop water requirement. Although the values for crop evapotranspiration and crop water requirement are identical, crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration.

In CropWat, crop water requirement (CWR) is expressed as ET_{max} for maximum potential evapotranspiration, and under optimal management and environmental conditions.

2.6 CropWat Description and Concept:

CropWat is a decision support system developed by the Land and Water Development Division of FAO. It uses the FAO (1992) Penman-Monteith methods for calculating reference crop evapotranspiration (FAO, 1998). CropWat computer model was used in the research to calculate reference evapotranspiration (ETo), crop water requirements (CWR) as well as irrigation water requirements (IWR) for the different chosen orchards types in the studying areas. The model support the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rain-fed conditions or deficit irrigation. The underlying sections simplify the calculation procedures used in the CropWat software.

2.7 Wastewater reuse in agriculture

Water consumption for agricultural purposes exceeds all other sectors. Hence, there is an increasing need for water reuse for irrigation of agricultural crops with treated wastewater (TWW) (Hamilton et al., 2007).

Wastewater reuse in agriculture is seen as one of the promising solutions that can assist partially in filling the gap in the growing needs for water (HWE, 2007). It is considered as a non-conventional water resource that needs better management.

In addition, the use of treated wastewater for irrigation would reduce the degradation of groundwater quality, enhance aquifer recovery, and reduce sea water intrusion (Al-Juaidi, 2009).

Irrigation with treated wastewater is considered as an environmentally sound wastewater disposal practice compared to its direct disposal to the surface or ground water bodies (Rusan et al., 2007), with careful planning and management. In addition, it enhances agricultural productivity: it provides water and nutrients, and improves crop yields.

However; it requires public health protection, appropriate wastewater treatment technology, treatment reliability, water management and public acceptance and participation. It must also be economically and financially viable (Kamizoulis et al.,2003).

Consequently, mismanagement of wastewater used for irrigation would create environmental and health problems to the ecosystem and human beings (Mohammad & Ayadi, 2004). In the Middle East and North Africa region, the interest in the reuse of treated effluent has accelerated significantly since 1980 for many reasons:

- Expansion of sewerage system networks and increasing the number of treatment plants
- Production of large quantities of wastewater which makes its use for agriculture a viable alternative
- Wastewater is a rich source of nutrients and can thus reduce the use of fertilizers
- The reuse is a safe disposal of wastewater which reduces environmental and health risks.

The treatment of wastewater to be used for irrigation is cheaper than that needed for the protection of environment. Regulations to discharge water into sea and streams or groundwater recharge are stricter than the reuse for irrigation (HWE, 2007). In addition, wastewater reuse potential in the Middle East and North Africa countries is very high due to extreme water scarcity.

2.7.1 Wastewater reuse in Gaza Strip

Shortage of water is perhaps the most crucial environmental problem. This shortage may be associated with deterioration of water quality due to excessive use of agricultural activities. However, surveys of environmental problems showed a big concern on water (Safi, 1998). In addition, water quality has become a major environmental concern. Nevertheless, water resources are limited due to geographical, geological and climatic conditions. Ground water is the only resource of water that used for multi-activities (El-Nahhal, 2006). The annual rainfall in the Gaza Strip ranges between 200-500 mm (MoA, 2008), There are three valleys in Gaza, moving through different locations: the northern part (Beit Hanon Valley), Gaza city (Gaza Valley) and the southern Zone (Alsalqa Valley). These valleys are almost dry and in some case are used for sewage discharge (El-Nahhal, 2006). In the Gaza Strip, the use of treated wastewater in agriculture is one of the strategies adopted for increasing water supply to face water scarcity, and is justified on agronomic and economic grounds but care must be taken to minimize adverse health and environmental impacts (Alobaidy et al., 2010).

There is a difficulty in wastewater reuse due the absence of reconnaissance of such water by the Palestinian public as a non-conventional resource. In addition, all reuse pilot-scale projects were a failure as no rational use of this water is organized in most cases. In addition, the lack of large-scale water reuse projects is due to the lack of funds and due to bad effluent quality from the existing sewage plants (Al-Sa`ed, 2007). The reuse of treated effluent may become realistic only if effective treatment systems are installed. These systems provide effluents that comply with irrigation standards.

One of the practices in Gaza Strip for using treated wastewater in agriculture was in 2003 through a French program called " Strategy of Agricultural Water Management in the Middle East ", implemented by PHG, in cooperation with the Ministry of Agriculture (MoA) and PWA (Abdo, 2008).

Two areas in Gaza Strip were selected for the pilot project. The first area was Beit Lahia in northern area at Om Al Naser village where TWW from BLWWTP was used to irrigate alfalfa plants of an area of about 13 dunum (dunum = 0.1 ha) (Abdo, 2008).

2.8 Benefits and risks of wastewater reuse in agriculture

Wastewater reuse in agriculture is considered as an environmentally sound wastewater disposal practice compared to its direct disposal to the surface or ground water bodies. Consequently, mismanagement of wastewater irrigation would create environmental and health problems to the ecosystem and human beings. Given these risks and benefits, countries seeking to improve wastewater use in agriculture must reduce the risks, in particular to public health, and maximize the benefits.

2.8.1 Benefits of wastewater reuse in agriculture

When properly planned, implemented and managed, wastewater irrigation schemes can have several benefits that accrue to the agricultural, water resources management, and environmental sectors.

Agricultural benefits:

Agricultural benefits may include: reliable, and possibly less costly irrigation water supply; increases crop yields, often larger than with freshwater due to the wastewater’s nutrient content; more secure and higher urban agricultural production, and contribution to food security; income and employment generation in urban areas; and improved livelihoods for urban agriculturalists (Jimenez et al., 2010).

Water resources management benefits:

In terms of water resources management, the benefits may include: additional drought-proof water supply, often with lower cost than expanding supplies through storage, transfers, or desalinization; more local sourcing of water; inclusion of wastewater in the broader water resources management context; and more integrated urban water resources management (Jimenez et al., 2010).

Environmental benefits:

Among the environmental benefits that may achieve well-managed wastewater irrigation schemes are the avoidance of surface water pollution-which would occur if wastewater was not used but discharged into rivers or lakes, and the avoidance of major environmental pollution problems, such as dissolved oxygen depletion, eutrophication, foaming, and fish kills (Mara & Cairncross, 1989). Conservation or more rational use of freshwater resources, especially in arid and semiarid areas, freshwater for urban demand, wastewater for agricultural use; reduced requirements for artificial fertilizers, with a concomitant reduction in energy expenditure and industrial pollution elsewhere; soil conservation through humus buildup and through the prevention of land erosion; and desertification control and desert reclamation, through irrigation and fertilization of tree belts (Mara & Cairncross, 1989).

2.8.2 Risks of wastewater reuse in agriculture

Microbial risks to public health:

In low and middle income countries, the greatest risks are primarily to public health from the microbial pathogens (disease-causing organisms) contained in domestic wastewater, including bacteria, viruses, protozoa and helminthes. Epidemiological studies carried out over the past four decades have linked the uncontrolled use of untreated or partially treated wastewater for edible crop irrigation to the transmission of endemic and epidemic diseases to farmers and crop consumers (Shuval & Mara, 1986). Actual risks of using untreated wastewater for irrigation include the increased prevalence of helminthes diseases (such as ascariasis and hookworm) to field workers and consumers of uncooked vegetables, and bacterial and viral diseases (such as diarrhea, typhoid, and cholera) in those consuming salad crops and raw vegetables (Shuval & Mara, 1986).

Chemical risks to public health:

Chemical risks are greater for developed countries where industrial wastewaters may be discharged to public sewers and contaminate municipal wastewaters. Chemical risks to human health may be caused by heavy metals such as cadmium, lead, and mercury; and by many organic compounds such as pesticides. There is also an increasing concern in such countries regarding an emerging class of "anthropogenic" chemical compounds, which include: pharmaceuticals, hormones and endocrine disruptors, antibiotics, and personal care products – although their long-term health effects are less clearly understood (Bhandari, et al., 2009).

Risks to crops:

The principal risk to crops is reduced crop yields if the quality of wastewater used for irrigation is unsuitable, for example by being too saline or having excessive concentrations of boron, heavy metals or other industrial toxicants, nitrogen, and/or sodium. Risks to plant health are reduced if there is little industrial effluent in the wastewater, but in all cases, five parameters should be monitored during the irrigation season: EC, SAR, B, TN, and pH (Westcot D.W., 1997).

Environmental risks:

Soil and groundwater pollution is the main risk of using wastewater in agriculture; the microbiological pollution of groundwater is a lesser risk as most soils will retain pathogens in the top few meters of soil except in certain hydro-geological situations like limestone formations.

Chemical risks include, among others, nitrates in groundwater from sewage irrigation, salination of soils and aquifers, and changes in soil structure from, for example, boron compounds common in industrial and domestic detergents. The key to controlling many of the chemical risks to humans, plants and the environment is to put in place effective industrial wastewater pretreatment and control programs. Of course, effective programs are not the norm in developing countries, so special attention has to be paid to chemical risks in such circumstances (BGS, 2011).

2.9 Regulations and standards of treated wastewater:

There is not a common regulation of wastewater reuse in the world due to various climatic, geological and geographical conditions, water resources, type of crops and soils, economic and social aspects, and country /state policies towards using wastewater influents for irrigation purposes. Some countries and organizations have already established reuse standards such as United States Environmental Protection Agency (USEPA), California, WHO, FAO, France, Italy. Most of the developing countries have adopted their own standards from the leading standards set by either FAO, WHO, California, etc (EPA, 2004).

2.9.1 Treated wastewater reuse pilots (Gaza Strip)

A French program called “Strategy of agricultural water management in the Middle East” is a good demonstration example for the Palestinian practice of treated wastewater reuse in agricultural production. Two areas were chosen for the implementation of this project in the Palestinian Territories which only initiated at the beginning of 2003: Gaza Strip and Al Bathan Al Farah valley in the West Bank (MoA et al., 2004). The program is coordinated by a Steering Committee (MoA, PWA, French Consulate, MREA) chaired by a MoA representative in Ramallah and each pilot project is managed by a technical committee (MoA, PWA, PHG, French Consulate, MREA). EQA participated as a regulator and evaluating the progress of the project and it environmental impacts during the site visits and inspections. Moreover, EQA contributes in reviewing the technical reports of the project prepared by the French Consultant MREA.

The project has selected two areas in the Gaza Strip: 1. Beit Lahia area where the treated wastewater coming from the Beit Lahia WWTP was available in unlimited quantities and a new experimental irrigated areas could be developed in large empty sandy dunes areas available around the village and 2. CAMP area (Coastal Aquifer Management Programme) area where TWW from the Gaza city WWTP could be used to irrigate existing citrus farms.

The farmers in Beit Lahia area is basically interested in alfalfa, considered the highest quality fodder. A “modern” variety called Hijazi was proposed by the MoA technicians. The excellent results of Jordanian farmers with a combination of Sudan Grass in summer and Rye grass in winter in their TWW irrigated areas (Madaba, Hashmieh) suggested these two crops could be tested too. Local farmers made limited experiments with maize, sorghum, plants of Olive trees, of a high and thin variety (supposed not to expand over irrigated fodders area) were given by the MoA and were planted in marginal locations (close to the fences).

An initial attempt of vegetables production had been done in a greenhouse inside the Northern WWTP but it was later abandoned due to the resistance of the consumers. Due to the good quality of water, the production of flowers (carnation) was initially considered but the Ministry of Agriculture decided not to use waste water for this production because of the hypothetics risks on export, especially for the Israeli market. The existence of an important Bedouin village with many animals and big areas of unoccupied sandy dunes has oriented the project to a demonstration of fodder production. The main observations in this pilot regards the water quality were (MoA et al., 2004):

- The sanitarian quality of the lake water was surprisingly good (The fecal coliforms are especially low for a treated waste water:
  - ✓ less than 50 counted coliforms / 100 ml, and have been decreasing during the period).
  - ✓ No salmonellas encountered
- The salinity of the water is medium (1.8 to 1.9 deciSiemens/m) and TDS 1300 ppm
- The chloride concentration is relatively high (300 ppm).
- SAR is around 5 which is not worrying for a 1.9 mS/cm water.
- The performance WWTP's operation, considering the effect of the lake, is acceptable (BOD less than 80 and COD less than 200)
- The quantities of Boron is relatively small (0.37 ppm)
- The heavy metals where in very limited concentration
- Total Nitrogen (Kheladi) is 30 ppm and nitrate (NO_3) is around 15 ppm.
- Phosphate (P) concentration is less than 3 ppm.
- Potasium (K) concentration is 30 to 35 ppm.

2.9.2 Advantages of reclaimed water Use

1. Reduces the demands on potable sources of fresh water.
2. Reduces the need for large wastewater treatment plants in case of reusing or recycling significant portions of wastewater
3. Diminish or reduce the volume of wastewater discharged, resulting in a beneficial impact on the aquatic environment and on the streams, rivers and ground water
4. Postponement of construction of additional water supply wells
5. Capital costs are not high and they are recoverable in a short time

6. Reclaimed wastewater is rich in nutrients that will increase agricultural production in water-poor areas

2.9.3 WHO guidelines

To ensure human health and to protect environments, WHO developed guidelines for wastewater reuse in agriculture and aquaculture since 1973. After a thorough review of epidemiological studies and other information, the guidelines were updated in 1989.

The most recent revision took place in 2006. These guidelines have been very useful, and many countries have adopted them in their wastewater and excreta use practices. The main features of WHO guidelines for wastewater reuse in agriculture are as follows:

- Wastewater is considered as a resource to be used safely;
- The aim of the guidelines is to protect against excess infection in exposed populations (consumers, farmworkers, populations living near irrigated fields);
- Fecal coliforms and intestinal nematode eggs are used as pathogen indicators;
- Measures comprising good reuse management practice are proposed alongside wastewater quality and treatment goals; restrictions on crops to be irrigated with wastewater; selection of irrigation methods providing increased health protection, and observation of good personal hygiene (including the use of protective clothing) (WHO, 1989);

2.9.4 Reclaimed water standards in the Mediterranean basin

"Water experts and politicians agreed that; there is an acute water shortage in the Middle East region and the problem must be addressed immediately and in a regional context, it is an issue which cannot wait" (Institute of Peace Implementation). Because irrigation has the largest water use in the world, reclaimed wastewater is used as a source of irrigation in the Mediterranean basin. This has many advantages in addition to the low cost water source; they are:

- Eliminating a part of fertilizers needed for plants
- Increases the available agricultural water resources
- Eliminates the need of expensive tertiary treatment
- It appears that irrigation with reclaimed wastewater may give some interesting effects on both the soil and the crop

"Wastewater reuse is often associated with environmental and health risks. As a consequence, its acceptability to replace other water resources for irrigation is highly dependent on whether the health risks and environmental impacts entailed are acceptable or not" (Angelakis & Bontoux, 1999). A review of the current regulations of wastewater reuse in some Mediterranean countries is considered here.

Most Mediterranean countries are arid or semiarid with mostly seasonal and unevenly distributed precipitations. Due to the rapid development of irrigation and domestic water supplies, conventional water resources have been seriously depleted. As a result, wastewater reclamation and reuse is increasingly being integrated in the planning and development of water resources in the Mediterranean region, particularly for irrigation.

2.9.4.1 Cyprus

The standards related to the use of reclaimed water for irrigation purpose in Cyprus are listed in Table 2.2. These regulations took into account the specific conditions in Cyprus to get the best performance of the reuse process.

Table 2.2 Quality Criteria of Irrigation with Reclaimed Water in Cyprus

Irrigation of	BOD	SS	FC	Intestinal Nematode	Treatment Required
Crops for human consumption	< 30 (mg / L)	< 45 (mg / L)	< 1000 (MPN / 100 mL)	Nil (/ L)	Secondary, storage > 1 week, disinfection or tertiary and disinfection
Fodder crops	< 30 (mg / L)	< 45 (mg / L)	< 5000 (MPN / 100 mL)	Nil (/ L)	Secondary, storage > 1 week, disinfection or tertiary and disinfection
Industrial crops	< 70 (mg / L)	-	< 10000 (MPN / 100 mL)	-	Secondary and disinfection

2.9.4.2 Israel

Israel was a pioneer in the development of wastewater reuse practices (Angelakis & Bontoux, 1999). It has achieved some impressive accomplishments in reclamation and reuse of wastewater, and at solving issues which arose from using RWW. The total amount of wastewater produced in Israel is approximately 500 MCM/yr including agriculture, industry, and other wastewater consumers. Almost all of the wastewater produced in Israel flows into the main sewage collection systems, while only 2.5% of the wastewater still flows into cesspits. Approximately 450 MCM/yr is being treated at 465 mechanical facilities and stabilization basins, using a variety of technologies. During 2007 total amount of RWW used for agriculture purpose was about 382 MCM. About half of the total amount has been treated to tertiary degree; the rest has been treated to a secondary degree (MERAP, 2010).

The use of reclaimed water in Israel must be accepted by local, regional and national authorities. Effluent must comply with the criteria outlined in Table 2.3. It is important to mention that; cost benefit analysis indicates that the cost of reclaimed water is very low in Israel; this is a driving force to obtain high percentage of reclaimed water (Angelakis & Bontoux, 1999).

Table 2.3: Reclaimed Water Use Criteria in Israel

Parameter	Group of Crop / main crops			
	Cotton, sugar beet, dry fodder seeds, forests	Green fodder, olives, citrus, bananas, nuts, almonds	Green belts, cooked and peeled vegetables, football fields	Vegetables eaten uncooked, parks and lawns
BOD_5 (mg / L)	60	45	35	15
SS (mg / L)	50	40	30	15
DO (mg / L)	0.5	0.5	0.5	0.5
FC (MPN / 100 mL)	-	-	250	12
Residual Cl_2 (mg / L)	-	-	0.15	0.5
Sand filtration	-	-	-	Required
Chlorination contact time	-	-	60 (min.)	120 (min.)
Distance from residential areas	300 (m)	250 (m)	-	-
Distance from paved road (m)	30	25	-	-

2.9.4.3 Tunisia

Tunisia RWW irrigation has had Government support since 1975, and since a severe drought in 1989, RWW use in irrigation has been a part of the Government's overall water resources management and environmental pollution control (World Bank, 2010). It is estimated that by 2020 about 20,000-30,000 ha, or about 7-10% of total irrigated area will be using RWW. The current rate of reuse is about 29%, reused for the cultivation of fruit trees, cereals, fodder crops and industrial crops as well as for golf courses and green spaces. Wastewater is also reused in recharges purposes and conservation of wetlands (Kamoun and Slimi, 2006).

Irrigation of vegetables eaten raw is prohibited. Therefore; most of the reclaimed water is used to irrigate citrus, olives, apples, cotton, tobacco and golf courses. Some hotel gardens were irrigated using reclaimed water.

Use of reclaimed water had been authorized by the Ministry of Agriculture in agreement with the Ministry of Environment and the Ministry of Public Health. These ministries set out the precautions to protect the workers, the consumers and the environment. Table 2.4 summarizes the Tunisian standards.

Table 2.4 Tunisian Standards of Reclaimed Water Use

Parameter	Max. allowed concentration
pH	6.5 – 8.5
EC (Scm^{-1})	7,000
COD (mg / L)	90
BOD_5 (mg / L)	30
SS (mg / L)	30
Intestinal nematode (No. / L)	< 1

2.9.4.4 Egypt

"No guidelines have yet been developed, but the 1984 Martial Law regulation prohibited the use of effluent for irrigation of crops unless treated to the required standards of agricultural drainage water. The irrigation of vegetables eaten raw with treated water, regardless of its quality, is forbidden". (Angelakis & Bontoux, 1999)

2.9.5 Palestinian Standards & Regulation

For a long time, Palestine did not have any specific wastewater regulations. References were usually made to the WHO recommendations or to the neighboring countries' standards (Egypt, Jordan).

Recently in Palestine (the West Bank & the Gaza Strip), there is a Palestinian Standard (PS) for the Treated Wastewater (PS-742-2003) which has been established by the Palestinian Ministry of the Environment and accredited by the Palestinian Standards Institute, after the establishment of Palestinian law in 1999, which states in (Article 29): "The Ministry (MENA), in coordination with the competent agencies, shall set standards and norms for collecting, treating, reusing, or disposing wastewater and storm water in a sound manner, which comply with the preservation of the environment and public health" (EQA, 1999).

The Palestinian standards developed in 2003 have general criteria for the treated wastewater reuse in agriculture:

- The treated wastewater must meet the specified standards that vary according to the planned use;
- When treated effluent is used for irrigation of fruit trees, cooked vegetables and fodder crops, irrigation must be ceased two weeks before collecting the products. Fallen fruit should be discarded;

- The adverse effect of certain effluent quality parameters on the soil characteristics and on certain crops should be considered;
- Use of sprinkler systems for irrigation is prohibited;
- Use of treated effluent in the irrigation of crops that can be eaten raw such as tomatoes, cucumber, carrots, lettuce, radish, mint, or parsley is prohibited;
- Closed conduits or lined channels must be used for transmission of treated effluent in areas where the soil permeability is high, which can affect underground and surface water that could be used for potable purposes;
- Dilution of treated water effluent by mixing at the treatment site with clean water in order to achieve the requirements of this standard is prohibited (EQA, 2003).

In spite of the fact that there are very limited activities in the Palestinian territories for using reclaimed wastewater due to many reasons, there is a great potential for the reuse of this water resource to meet increasing agricultural water demand as a main objective of the Palestinian water sector. The total volume of treated urban wastewater for reuse is projected to be 12.1 MCM/yr for the main Palestinian cities by the year 2010. In comparison, the total water demand is projected to increase by 50 MCM/yr over the years 2005-2010 (MERAP, 2010). The reuse of treated wastewater could be an important alternative to solve the water deficit crisis in Gaza Strip. According to the Water Sector Strategic Planning Study, about 20,000 dunums are to be irrigated by RWW in the year 2010 and this will increase to about 60,000 dunums in the years 2020. The existing four WWTPs (Beit Lahia, Gaza, KhanYunis and Rafah) are heavily overloaded as a result of the rapid population growth. Currently, most of the effluent discharged from the four existing WWTPs in Gaza Strip is disposed into the Mediterranean Sea. Although the quality of the effluent from Gaza and even Beit Lahia WWTPs would nearly meet class C standards which are progressively match irrigating citrus, fodder crops and olives (EQA, 2005).

Table 2.5: Palestinian Standards for Irrigation and Recharge

Parameter	Palestinian Standards	
	Irrigation	Recharge
BOD (mg/l)	20-60	20
TSS (mg/l)	30-90	30
TDS (mg/l)	1500	1500
EC (ms/cm)	-	-
T-N (mg/l)	45	100
Na (mg/l)	200	230

Cl (mg/l)	500	600
SAR	9	-
B (mg/l)	0.7	1
F.coliform (MPN/100ml)	200-1000	200-1000
Nematodes (ovum/l)	< 1	< 1

2.10 Related studies:

- **Al-Dadah, 2013** employed a research to prove that using treated wastewater providing sound solution to water scarcity and potentially cover half of the total agricultural water demand in GS. Wastewater reuse could provide a mitigation solution to climate change through the reduction in greenhouse gases by using less energy for wastewater management compared to that for importing water, pumping deep groundwater, seawater desalination, or exporting wastewater, and enrich the deteriorated soils in GS with more organic matter which lowering the application of chemical fertilizers.
- **Ghabayen & Salha, 2013** carried out a research to estimate the agricultural water consumption using ArcMap ArcGIS based approach and utilizing the available information of land use, rainfall, and other meteorological data where total of 49 computation procedures and processes were built in the model. The total annual crop water requirement is calculated to be 65 MCM. Knowing that the average annual well abstraction is 85 MCM; the losses due to conveying system deficiency, irrigation techniques, and over application are estimated at 24 %.
- **Al-Najar, 2011** conducted a research to integrate Cropwat model with GIS techniques to estimate the irrigation water requirements for the most common cultivated crops (citrus, almonds, date palms, grapes) and comparing the results with the farmer irrigation practices. The main results of the model show that the farmers use about 20 to 30% excess irrigation water than required for the common cultivated crops. Irrigation water quality is not optimal in the Gaza Strip, chemical analysis of irrigation wells indicate high salinity and SAR ratio.
- **Attaallah, 2013** conducted a study to investigate the short-term effect of irrigation with reclaimed wastewater from Gaza Wastewater Treatment Plant on physiochemical properties of soil, groundwater and fruits. The results show that significant difference in EC, TDS, NO3, Cl-, Mg+2, Ca+2, Na+ and OM were reported, particular at top soil layer (0-30 cm) more than (30-60 cm) layer. Results also showed no microbial contamination in the olive and citrus fruits in. Additionally, the levels of the heavy metals were reported to be low. Olive oil quality parameters indicated no significant variation in refractive index, free acidity, peroxide value and acid value extracted from olive fruits from both plots.

- **Nassar et al., 2010** discussed the most feasible option of proposed three main disposal: use in irrigation, aquifer recharge and disposal to Wadi Gaza. The results show that the predicted effluent quality is suitable for irrigation of a wide range of crops, with only marginal reduction in potential yield provided that the irrigation with leaching regime is appropriate to control soil salinity. The most appropriate effluent reuse strategy should be dependent upon direct supply for crop irrigation and the surplus recharged to the aquifer.
- **Al-Juaidi, 2009** used the water allocation system model of Fisher et al. (2005) to find the applicability of using treated wastewater in agriculture to reduce the stress on freshwater supply in Gaza Strip. The applicability of different management options were evaluated using the net benefit and shadow value of water in each sector. The key findings from this study is the shadow value of water and water availability are inversely proportional. The introduction of treated wastewater has a large impact on the overall availability of water in Gaza Strip because it effectively frees up freshwater for use by urban and industrial sectors and allows for a second use of effluent by agriculture. Also Use of treated wastewater in agriculture has a high impact on reducing the agricultural water prices. The urban water prices also decreased when use of treated wastewater is considered.
- **Hamdy, 2001** summarize in his research the solution to the problem of water resources lies in rational management which should be concerned both with supply and demand grounded on solid scientific and technical foundations and necessitating an interdisciplinary approach to the ecological, economic and social problems. Such management should aim at promoting the use of water resources in such a way as to ensure the satisfaction of society's needs while preserving them for the future.
- **Hamdy & Liuzzi, 2005** conducted a research to suggest a tool to overcome water scarcity and quality constraints in the Mediterranean region by developing an appropriate water pricing systems, aimed at promoting efficiency and sustainability of water management as well as the cost of water services offers high potentiality.
- **Al-Yaqubi, et al., 2007** presented overall guidelines for the management through year 2020, with associated investment requirements for infrastructure facilities to meet all goals and objectives. It has been estimated that a capital investment program of about US$1.5 billion is needed to finance the implementation of such plan. It has been concluded that seawater desalination as well as brackish water desalination are the main components of the domestic water management plan that will have overall beneficial impacts on the socioeconomic aspects.
- **Jaradat, 2010** evaluated the existing water demand and supply conditions and expected future demand and supply scenarios taking into account the different operating policies and factors that affect demand. Three scenarios are (1)Current State (2) when economy moves on but no development in the political conditions. (3) Independent State with economy moves on. And the results shows that the

water demand will vary according to three scenarios; the water demand will increase from 201 MCM in scenario 1, to 266 MCM in scenario 2 to 371 MCM in scenario 3 by the year 2020. And the water demand gap will be filled if scenario 3 achieved; it turns out to be zero until year 2018. Even that the gap will be 74 MCM in scenario 2, and 105 MCM in scenario 1.

- **Sanjaq, 2009** attempted to develop an integrated water resources management for the area which is served by Jerusalem Water Undertaking (JWU), by using (WEAP) model. WEAP model allows the simulation and analysis of various water allocations, the concept of regional utilities and its impact on water management was evaluated. Three management options for JWU are investigated. The three options which were developed into WEAP and tested as follows: Option 1: pumping water from Eastern Aquifer Basin Option 2: pumping water from Western Aquifer Basin Option 3: pumping water from Both Aquifer Basins. The results obtained in this study show that the service area of the central water utility should be connected together to allow better management of the available water resources.
- **Nazer et al. (2010)** had built an optimization model to the irrigation water allocation in the West Bank. The Solver function enabled by Microsoft Excel is used to build the linear model because it is simple to use and easy to manipulate for end users. Five agricultural zones and five fruit and vegetable crops under three scenarios were considered. The main goal was to maximize the profit under the constraints of land and water availability as well as local consumption of the crops. It was found that changing the cropping pattern may reduce water used for irrigation by 10%. It was also found that water scarcity problem can be well coped with if rain-fed agriculture replaces irrigated agriculture.
- **Pereira et.al., 2002** Discussed water scarcity and how supply management to cope with water scarcity, giving particular attention to the use of wastewater and low-quality waters, including the respective impacts on health and the environment as water scarcity is requiring that waters of inferior quality be increasingly used for irrigation.
- **Cirelli et.al., 2012** analyzed a treated wastewater (TWW) reuse scenario in a semi-arid climate region of southern Italy. The effects on the bacteriological quality and yield components of vegetable crops irrigated with TWW were evaluated. The microbiological quality of the products (i.e., eggplant and tomato) was generally maintained, although the Escherichia coli content in TWW was often over the limits set by the Italian government. Potential contaminations scenarios were assessed based on Italian and WHO guidelines.
- **Agrafioti et.al., 2012** concluded that the agricultural irrigation with treated wastewater could be implemented on the island of Crete. Analysis of effluent qualitative data indicated that 13 out of 15 WWTPs throughout Crete meet the proposed criteria for olive tree and vineyard irrigation without any additional treatment. However, vegetable irrigation requires further advanced tertiary

treatment. Estimation and visualization of the irrigated land showed that wastewater can be used as an alternative water resource to irrigate a significant agricultural area. Consequently, wastewater reclamation and reuse can reserve great amounts of fresh water which can be used in order seasonal water scarcity to be confronted.

2.11 Concluded Remarks

Previous studies concentrated on the general aspects of water resources in Palestine and did not emphasize the future of agriculture in the Gaza Strip and how to overcome the scarcity of water supply for agricultural practice. Some studies recommended that to use treated wastewater for crop irrigation to reduce the stress on freshwater supply in Gaza Strip (Al-Dadah, 2013; Nassar et al., 2010; Al-Juaidi, 2009). Also other studies conducted that to investigate the effect of irrigation with reclaimed wastewater, the results showed that no microbial contamination in the olive, citrus and fruits. Additionally, the levels of the heavy metals were reported to be low (Attaallah, 2013; Agrafioti et.al., 2012; Cirelli et.al., 2012).

It is clear from the previous research that management of water resources for agricultural sector and planning agricultural practice using WEAP model have not been conducted in GS, till now. Thus, this new research (Management of Water resources for Agriculture sector at Gaza strip using WEAP model, Khanyounis governorate as a case study). WEAP model to be built will allow the simulation and analysis of various scenarios for using treated wastewater and changing crop pattern. In addition the model will find the best scenario to reduce the stress on fresh water supply in Khanyounis governorate .

Also this research might be considered as the first contributions in management water resources for agricultural sector using WEAP model.

CHAPTER

3

Study Area

3.1 Introduction

Khanyounis governorate is one of the five governorates of the Gaza Strip. Gaza Strip is located in an arid area with scarce water resources. It is a part of the Palestinian coastal plain in the south west of Palestine as shown in Figure 3.1, where it forms a long and narrow rectangular area of about 365 km2, with 45 km length, and between 5 and 12 km width.

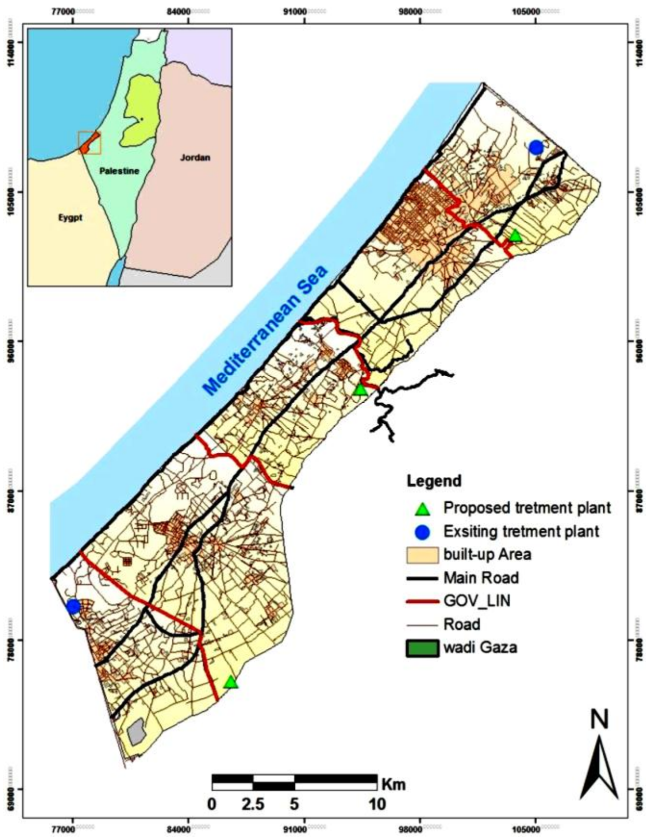

Figure 3.1: Map of Gaza Strip

Nowadays, G.S five governorates are: Northern, Gaza, Middle, Khanyounis and Rafah. It is located on the south-eastern coast of the Mediterranean Sea, between longitudes 34° 2’’ and 34° 25’’ east, and latitudes 31° 16’’ and 31° 45’’ north. The Gaza Strip is confined between the Mediterranean Sea in the west, Egypt in the south. Before 1948, it was part of Palestine under the British mandate. From 1948 to 1967, it was under the Egyptian administration. From 1967 until 1994, the Gaza Strip was under Israel occupation. According to the peace agreement between Israel and the Palestinian, the Gaza Strip has been under the Palestinian Authority control since May, 1994. (PCBS, 2007; UNEP, 2009).

Khanyounis Governorate is located in the southern part of Gaza Strip .Its district capital is Khanyounis City. In 2007, About 280 thousand inhabitants are living in Khanyounis. The Khanyounis governorate consists of six municipalities: Khanyounis, Bani Suhaila, Abasan El-Kabira, Abasan El-Saghira, Quarrara, Al Fakhari and the Khaza'a as shown in Figure 3.2.

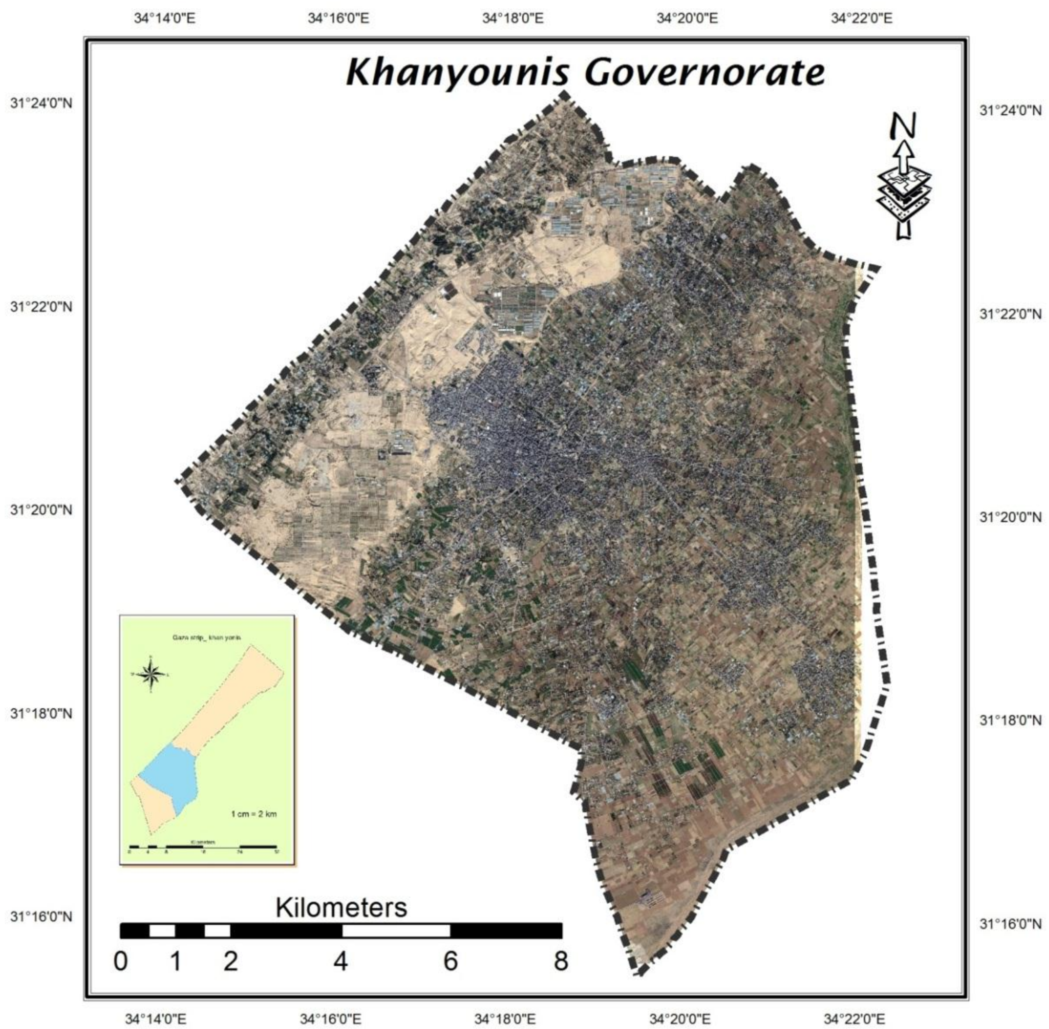

Figure 3.2:*Khanyounis Governorate map*((prepared by researcher)

3.2 *Physical Settings*

3.2.1 Climate

Khanyounis as a part of Gaza Strip has a characteristically semi-arid climate and is located in the transitional zone between a temperate Mediterranean climate in the west and north, and an arid desert climate of the Sinai peninsula in the east and south. In this study, the climate parameters are average monthly and annually. Regarding the rainfall data and measurements of Khanyounis governorate, the wet season starts in October and extends to April while the dry season occurs between May to September.

3.2.2 Temperature, Humidity and Solar Radiation

Figure 3.4 presents the maximum, minimum and mean monthly air temperatures as observed in the meteorological station of Gaza city (closed to Khanyounis temperature) for the period lasting from 1999 until 2005. Temperature gradually changes throughout the year, reaches its maximum in August (summer) and its minimum in January (winter), average of the monthly maximum temperature range from about 15.6 C° for January to 27.84 C° for August. The average of the monthly minimum temperature for January is about 12.85 C° and 27.6 for August.

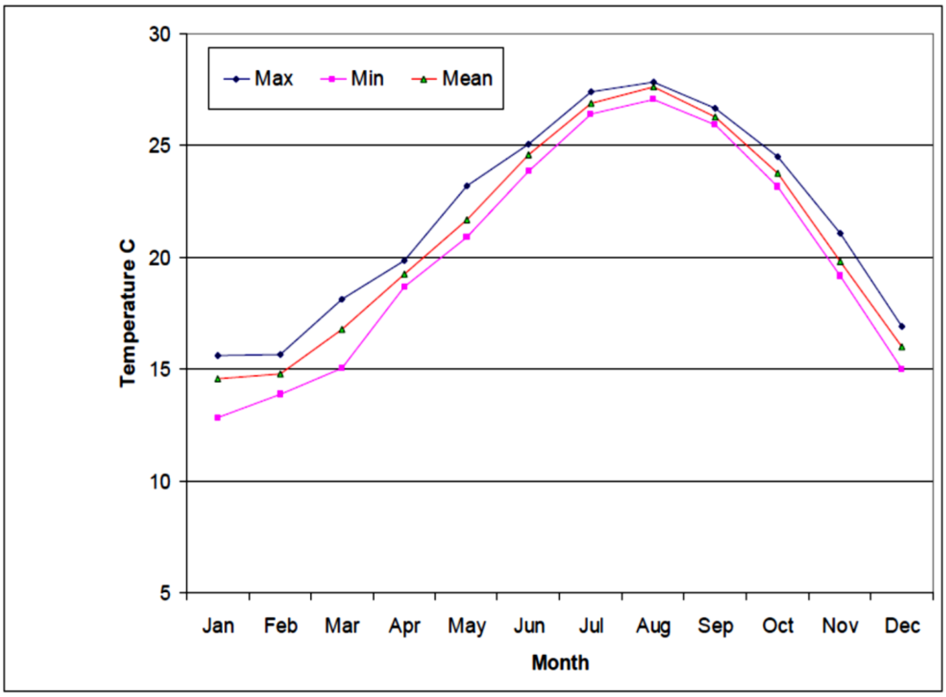

Figure 3.3: ***Mean monthly maximum, minimum and average temperature (C°) for the Gaza Strip (period 1999 – 2005)***

The daily relative humidity fluctuates between 65% in daytime and 85% at night in summer, and between 60% and 80% respectively in winter. The mean annual solar radiation amounts to 2200 J/cm2/day (Metcalf & Eddy, 2000).

3.2.3 Rainfall

The rainfall data of Khanyounis is based on the data collected from the main two rain stations located in Khanyounis city and Khaza'a as shown in Figure 3.4. Daily rainfall data are available for Khanyounis station since 1985 but for Khaza'a station since 1999.The average rainfall in Khanyounis governorate from 1999 to 2008 was 263.5 (mm/year) as an annual precipitation as shown in Table 3.1.

Table 3.1 : Average yearly precipitation in Khanyounis governorate from 1999-2012 (source: MoA, 2013)

Year	Readings of Gauge(1) **(mm/ year)**	Readings of Gauge(2) **(mm/ year)**
1999/2000	191.80	142.20
2000/2001	381.00	284.30
2001/2002	311.70	258.50
2002/2003	298.00	261.20
2003/2004	204.40	184
2004/2005	373.00	367.70
2005/2006	270.50	214.00
2006/2007	252.00	255.80
2007/2008	159.30	151.00
2008/2009	271.80	207.80
2009/2010	186.10	161.00
2010/2011	187.60	142.00
2011/2012	348.20	280.00
Annual Precipitation (mm/year)	**264.26**	**223.80**

3.2.4 Reference Crop Evapotranspiration (ET_o)

ET_o is small in winter about 1.3 to 1.6 mm/d, and reaches its maximum in summer at about 6 mm/d. The mean monthly evaporation in Khanyounis Governorate varies significantly throughout the year. The monthly average evaporation over 25 years in Khanyounis varies between maximum of 194 mm in July and minimum of 51 mm in January, with an annual average evaporation of 1410 mm.

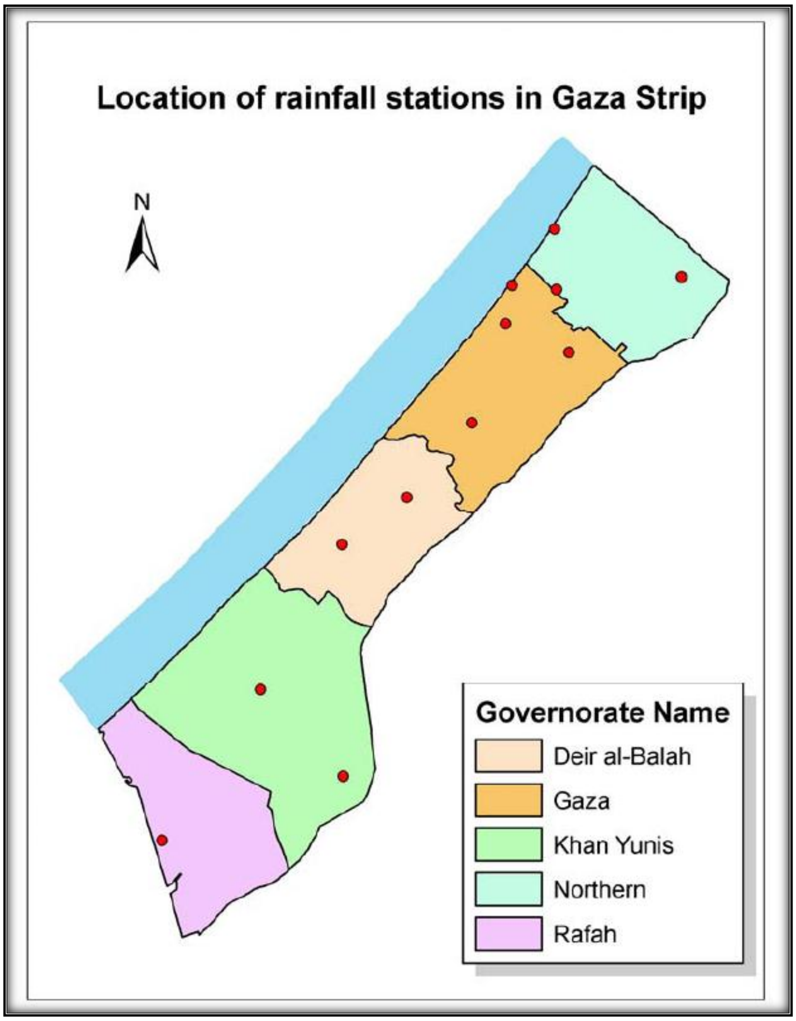

Figure 3.4: Locations of rain stations in the Gaza Strip (PWA, 2000)

3.2.5 Topography and Soil

The Gaza Strip topography is characterized by elongated ridges and depression parallel to the coastline, dry streambeds and shifting sand dunes. They are narrow and consist of "Kurkar" sandstone. The major depressions are filled with alluvial sediments from storm water (Aish, 2004). Land surface elevations range from mean sea level (MSL) to about 100 meters above the mean sea level at the eastern areas Figure 3.5 shows the soil distribution map of Gaza Strip.

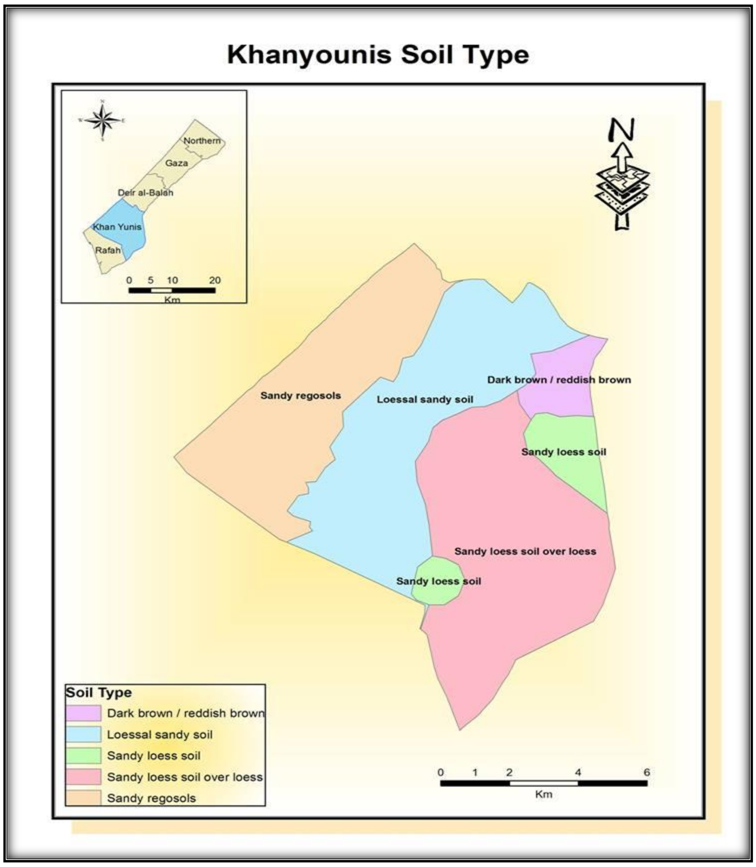

Figure 3.5*:* Soil Classifications in Khanyounis Governorate (MOPIC, 2004)

3.2.6 Land Use

The land use map of Khanyounis as shown in Figure 3.6 The map is based on the regional plan developed by central committee in the Ministry of the local government (MoLG, 2005). The land as shown in figure 3.6 is scarce and the pressure on it is increasing rapidly for all kinds of uses; urban, industrial, and agricultural uses. Agricultural land occupies about 72 km^2, which is about to 65% of the total area of the Khanyounis governorate. It is expected that future expansion will be for the domestic use only.

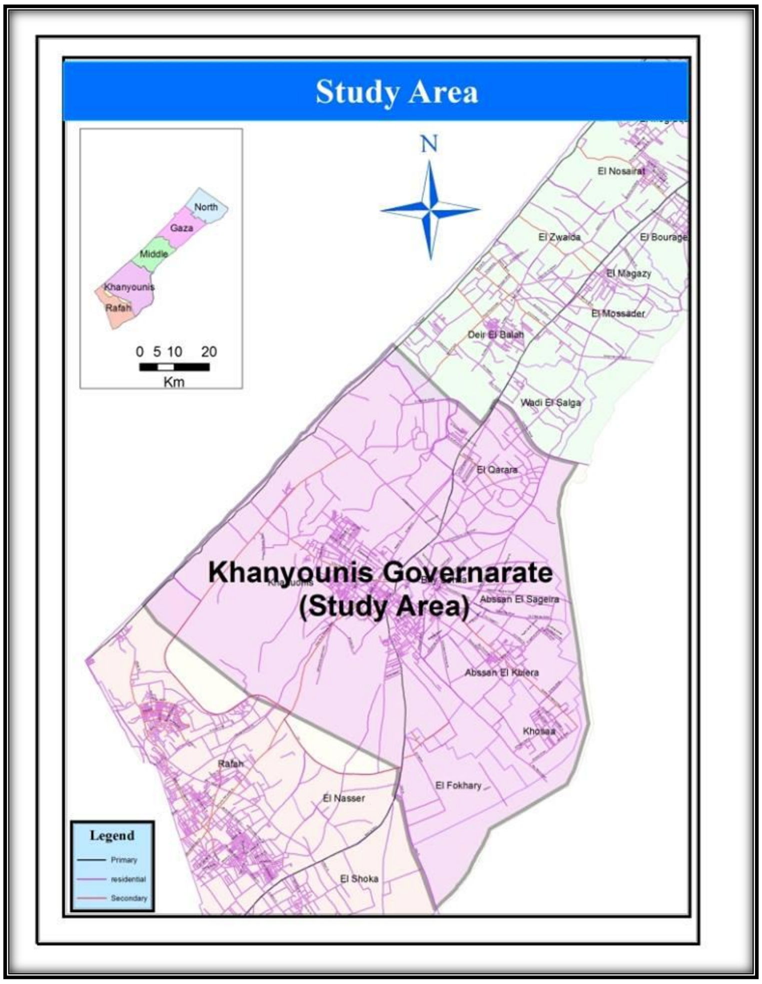

Figure 3.6: Location map of Khanyounis Governorate (MoP, 2005)

3.3 Hydrogeology

3.3.1 Description of the Coastal Aquifer

The coastal aquifer of the Gaza Strip (included Khanyounis governorate) is part of a regional groundwater aquifer system that extends north up to Haifa, and south into Sinai coast of Egypt. The coastal aquifer consists primarily of Pleistocene age Kurkar group deposits including calcareous and silty sandstones, silts, clays, unconsolidated sands, and conglomerates. The coastal aquifer is generally 10-15 kilometers wide; the Kurkar group forms a seaward sloping plain, which ranges in thickness from 0 m in the east, and about 100 m at the shore in the south, and about 200 m near Gaza City.

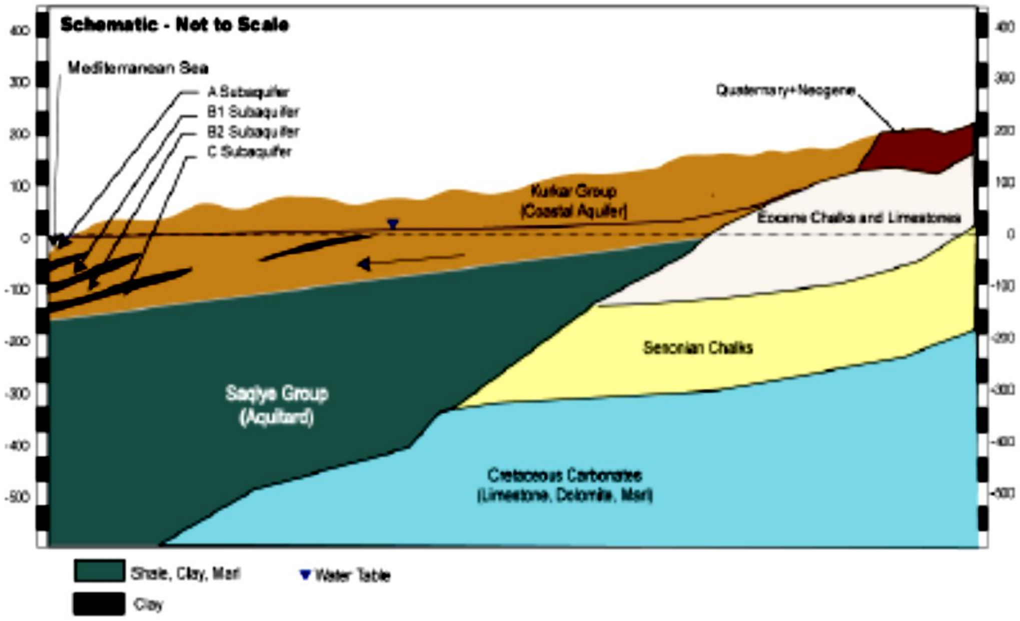

Figure 3.7*: Generalized Cross Section of the Coastal Plain, (Dan. Greitzer,1967)*

At the eastern Gaza border, the saturated thickness is about 60-70 m in the north, and only a few meters in the south near Rafah. Near the coast, coastal clay layers extend about 2-5 km inland, and divide the main aquifer into three subaquifers, referred to as subaquifers A, B1, B2, and C. A conceptual geological cross-section of the coastal plain geology is presented in Figure 3.7.The base of the aquifer is marked by the top of Saqiya formation (Tertiary age), it is a thick sequence of marls, clay stones and shale that slopes towards the sea, with low permeability and approximately 400-1000 m thick wedge beneath the Gaza Strip (Metcalf & Eddy, 2000; Qahman and Zhou, 2001).

3.4 Groundwater

Ground water is the most precious natural resource in the Gaza Governorates as it is the only source of water supply for domestic and agricultural use. Under natural conditions, groundwater flow in the Gaza Strip is towards the Mediterranean Sea, where it discharges to the sea. However, pumping over 50 years has significantly disturbed natural flow patterns. Large cone of depression have formed in the north and south where water levels are below mean sea level, including inflow of seawater towards the major pumping centers. In the northern-area of the Gaza Strip groundwater levels dropped by 8 meters between year 1935 and 1969. This drop is most apparent in the north due to extensive of groundwater exploitation at the eastern-northern border of the Gaza strip and due to Israeli activities between year 1948 and 1967. In all the Gaza Strip, between years 1970 and 1993 groundwater levels dropped by almost 2 meters on average. This drop is most apparent in the south as a reflection of lower recharge from rainfall in this area. In the north, most wells exhibit a relatively slower drop in this period due to higher recharge rate. Depth to water level of the coastal aquifer varies between few meters in the low land area along the shoreline, and about 70 m along the eastern border. The groundwater elevation map for KhanYounis governorate is illustrated by Figure 3.8. It shows sensitive area for groundwater depression where the groundwater level elevation drops more than 12m below mean sea level. This drop in the groundwater will led to lateral invasion of seawater due to pressure difference and direct contact with the aquifer, and also vertical invasion from deep saline water. This invasion laterally and vertically will affect the overall groundwater quality in the system.

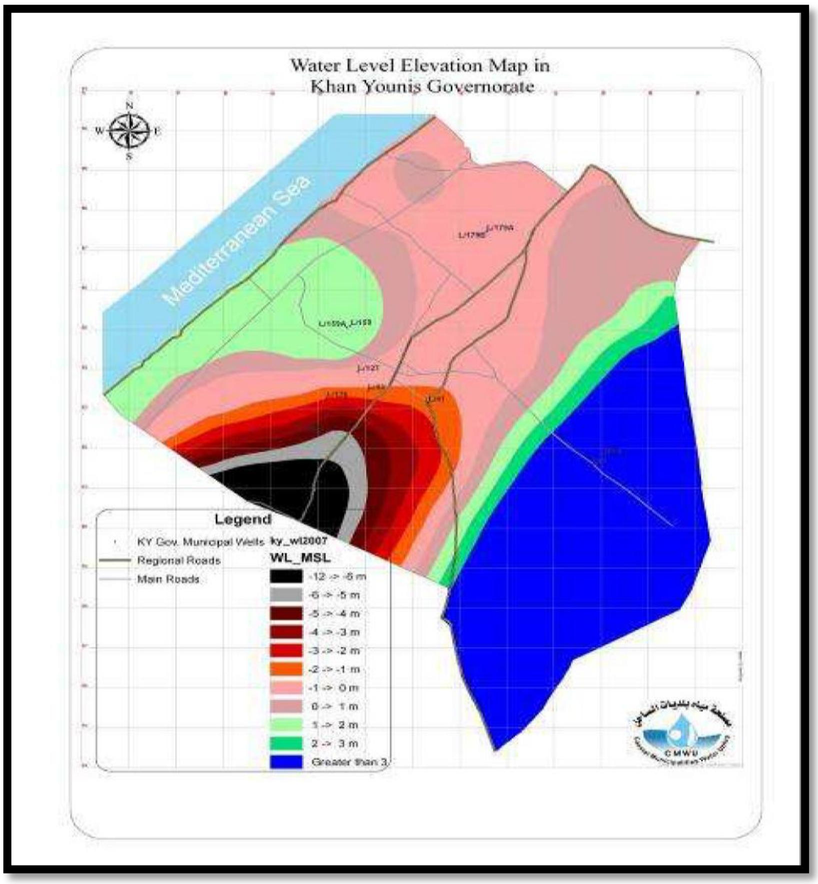

Figure 3.8*: Average groundwater table levels in Khanyounis Governorate for year 2007.*

Water quality of the coastal aquifer underlying Gaza has deteriorated harshly. The main groundwater quality problems are elevated chloride and nitrate concentrations. For simplicity, the reference level over which the water is to be considered a source and under which the water is to be considered a sink is set as follows based on the World Health Organization drinking water guidelines:50 mg/l for $NO3^-$, 250 mg/l for Cl^-.

3.4.1 Nitrate:

90 per cent of Gaza's water samples were found to contain nitrate concentrations that were between two and eight times higher than the limit recommended by the World Health Organization (WHO). Organic fertilizers and wastewater are the main causes of the nitrate contamination in the groundwater, followed by sewage sludge and artificial fertilizers. Isotopes are variations of the same chemical element that have a different number of neutrons in their nuclei. 18O and 15N are stable, i.e. non-radioactive, isotopes that are heavier than "normal" oxygen (16O) or nitrogen (14N) and can therefore be measured using a mass spectrometer. The lower 15N nitrogen isotope values in the sewage sludge indicate that the nitrate in the Gaza groundwater comes primarily from manure used as fertilizer. Between 2001 and 2007 samples from 115 municipal wells and 50 private wells have been taken on seven occasions. Nitrate concentrations of between 31 and 452 milligrams per liter were detected. Only 10 of the 115 municipal wells examined were found to have a nitrate level below the WHO guideline value. The situation with the private wells was equally serious: apart from three, all the wells were found to have nitrate levels that were between five and seven times higher than the WHO recommendations.

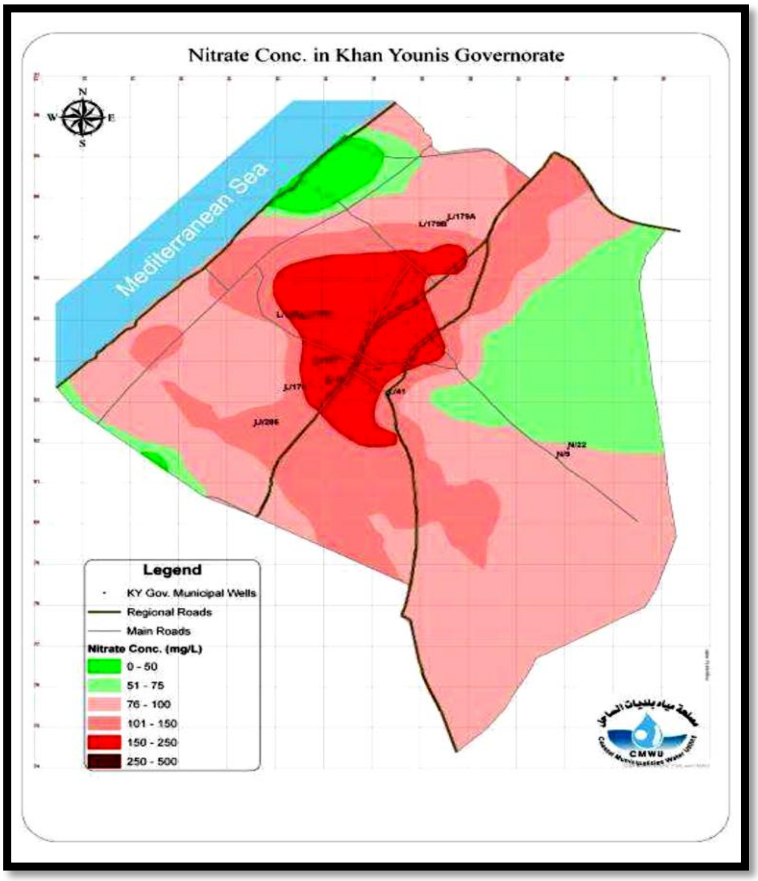

Figure 3.9*: Average nitrate concentrations in groundwater in Khanyounis Governorate for year 2007*

The nitrate concentration in the area surrounding both the wastewater treatment plant and the suggested infiltration basin exceed the level recommended by the WHO. As shown by the nitrate level groundwater in Khanyounis governorate, Figure 3.10. , it is more than 100 mg per liter.

3.4.2 Chloride:

High levels of chloride in the groundwater cause high salinity in the water supply. Less than 10% of the aquifer's yield is water meeting the WHO drinking standard (i.e. more than 250 mg/l). Some agricultural are currently reporting salinity levels of more than 1200mg/l. Sources of high chloride content have been determined to be; seawater intrusion, lateral flow of brackish water from east in the middle and southern area and up-coning of the brine water from the base of the aquifer. The sudden rise in salinity is entirely consistent with entrainment of seawater wedges. The coastal aquifer holds approximately 5000 MCM of groundwater of different quality. However, only 1400 MCM of this is "fresh water", with chloride content of less than 500 mg/l. This fresh groundwater typically occurs in the form of lenses that float on the top of the brackish and/or saline ground water. That means that approximately 70% of the aquifer are brackish or saline water and only 30% are fresh water.

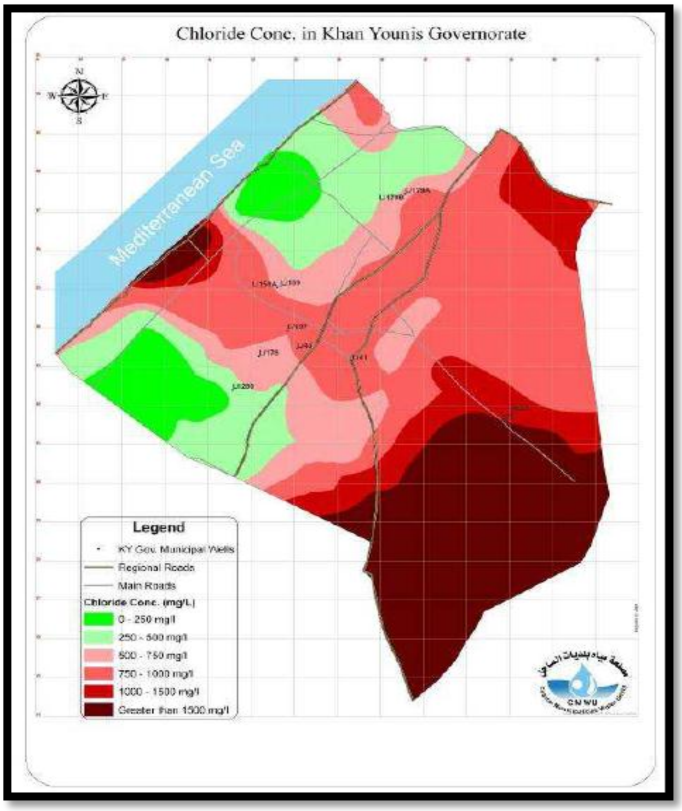

Figure 3.10*: Average chloride concentrations in groundwater in Khanyounis governorate for year 2007.*

The chloride level in the groundwater in Khanyounis governorate varies from less than 250 mg per liter in some western areas to more than 1500 mg per liter in the eastern area, as shown by Figure 3.10. However, the concentration in the groundwater beneath both the wastewater treatment plant and the infiltration basin in Khuza'a is more than 1500 mg /l.

3.5 Current Status of Wastewater Treatment and Reuse

Years of neglect during the occupation from 1967 to 1994 have created severe environmental problems in West Bank and Gaza. Lack of wastewater treatment plants of sewerage systems and of wastewater collection for recycling led to the uncontrolled discharge of wastewater into the environment. There were insufficient financial resources within the Palestinian community to pay for new wastewater collection, disposal and treatment systems. Israel was collecting taxes from Palestinians through the Israeli Civil Administration, but they never employ the money for the infrastructure for the Palestinian communities. The situation is worsened by the discharge of untreated wastewater from Israeli colonies (MEDAWARE, 2004).

The percentage of population connected to sewer networks in Palestine counts for approximately 45.8% distributed as 66.3% in Gaza Strip and 34.6% in West Bank while cesspits and septic tanks receive the rest. (MOH, 2004). There are seven main wastewater treatment facilities in the Palestinian Territories; three are located in Gaza strip while the rest in the West Bank.

3.6 Current Status of Wastewater Treatment and Reuse in Gaza Strip

There are four wastewater treatment plants operating in the Gaza Strip: Jabalia in the north, Gaza in the Gaza City, Khanyounis and Rafah in the south see Figure 3.11.

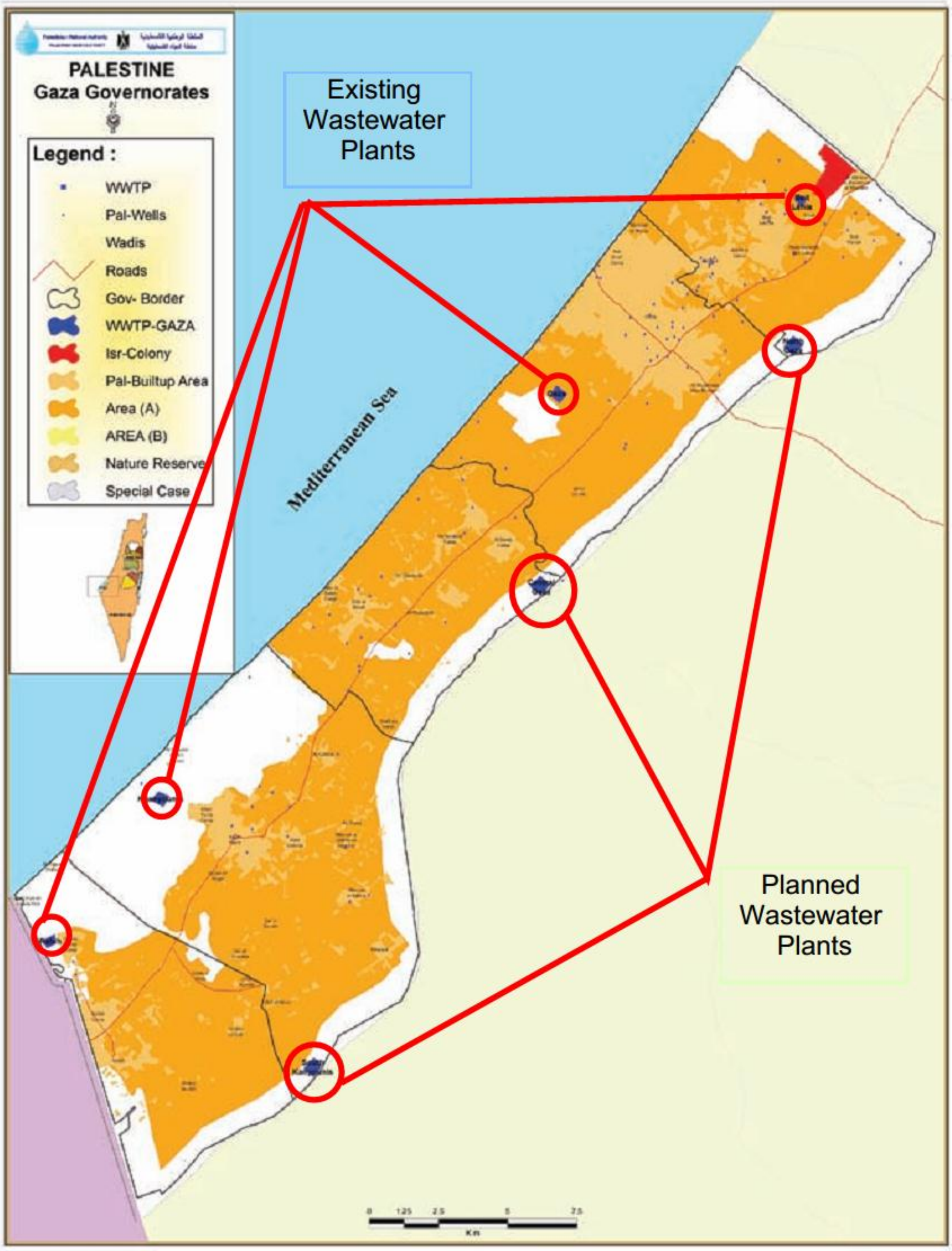

Figure 3.11 : Existing and Planned Wastewater Plants in the Gaza Strip *(PWA ,2011)*

The type of treatment, quantity and final disposal of each plant is summarized in Table 3.2 The existing three plants are heavily overloaded as the actual flow exceeds the design flow. Blocked pipes and flooded manholes are daily events in Gaza Strip. The total capacity of the existing three WWTPs is approximately 41. MCM/year.

Table 3.2: General features of wastewater production and collection in Gaza Strip (PWA , 2011).

Governorate	Population Capita	Connect to Sewage network (%)	Sewage Production (m3/day)	Treatment Availability	Final Destination
Northern	290, 000	80%	23,000	Available Partially Treatment	100% Infiltration basins East & North of Gaza Strip
Gaza	550, 000	90%	60,000	Available 80% Partially Treatment & 20% Raw	(100% to sea)
Middle	220, 000	75%	10, 000	Not Available	100% Wadi Gaza and indirectly to the Sea 10,000 Raw
Khanyounis	280, 000	40%	10,000	Available Partially Treatment	100% to sea
Rafah	185, 000	75%	10,000	Available partially Treatment	100% to sea
TOTAL	**1,525,.000**		**41 Mcm/ yr**		**33 Mcm /y To sea**

The Palestinian Water Authority estimated that at least 92 MCM of recycled wastewater would be available for agriculture reuse by the year 2020. Field measurements and future forecasting for wastewater quantities from the networks agree with these figures (**Afifi, 2006).** Table 3.3. presents the annual wastewater quantities generated in GS.

Table 3.3: Annual potential of wastewater generation in GS, (Afifi, 2006)

YEAR 2005	2000	2005	2010	2015	2020	2025
Population in Million	1.121	1.34	1.84	2.29	2.58	2.91
Water Consumption MCM	45.02	58.81	80.65	116.89	131.87	148.72
Wastewater generation MCM	36.02	47.05	64.53	93.51	105.50	118.98
% connected to network	50.0	65.0	75.0	85.0	90.0	95.0
Treated Effluent MCM/yr.	18.01	30.58	48.39	79.48	94.95	113.03

3.7 Khanyounis Wastewater & Treatment Plant (KY WWTP)

The Gaza Wastewater and Drainage Master Plan proposes 3 central wastewater treatment plants (KY WWTP) in the Gaza Strip, all to be located within the agricultural areas close to the eastern borders of the Gaza Strip. An activated sludge process with extended aeration will be the process for each plant enabling nitrogen removal .The southern KY WWTP will serve the Governorate of Khanyounis. Figure 3.11 provides a general layout of these components in relation to the location in Khanyounis Governorate and Gaza Strip.

3.7.1 Background and Previous Considerations

At present, nearly 60% of the population of Khanyounis city is temporarily served by the new established public sewerage collection system. But due to the absence of wastewater treatment plant, the collected wastewater is pumped to the existing main storm water box culvert, which in turn flows by gravity to a storm water infiltration pond located in the northwestern side of Khanyounis city.

The municipal wastewater strategic development plan aims at constructing an extendable and phased sewage system in line with the available resources. Although the strategic plan of the project is to design and construct an extendable KY WWTP with effluent capacity for the year 2025, the first phase of KY WWTP will be executed based on 2018 estimated capacity.

The city of Khanyounis is divided into two catchment's zones, where the collected wastewater is drained by gravity to two main pumping stations (PS # 2 & PS # 3) located in the lowest points of the city center. Through pressure and conveyance pipelines, the effluent of these two pumping stations is raised to the main pumping station (PS # 8) located in the eastern part of the city. From Pumping Station # 8, the collected wastewater of KhanYounis city will be pumped to the proposed KY WWTP located in the eastern part of the KhanYounis Governorate.

The proposed site of the KY WWTP is located south-east of Khanyounis city. The closest point of the permanent eastern site of KY WWTP is located far by around 450 m from the eastern borders of the Gaza Strip in one of the sites' corners, and by 750m in the other sites eastern corner. Khanyounis municipality owns the site of the KY WWTP. The available area for the proposed KY WWTP is 116 dunums (11.6 hectares). The shape of the site is long and narrow (670 meters X 170 meters). The major result of the design layout is that the planned facilities for Phase 1 and Phase 2 of the KY WWTP can be located within the available site area.

3.7.2 Process Design Criteria and Considerations

The treated water quality requirements are summarized in Table 3.12 as defined in the Detailed Design Report (February, 2010).

Table 3.12 : Treated wastewater requirement of the plant

Parameter	Unit	Required effluent quality for KY WWTP
BOD5	mg/l	< 20
Suspended solids, SS	mg/l	< 15
Total nitrogen	mg/l	< 25
Ammonium nitrogen, NH4-N	mg/l	<10
Nitrate nitrogen, NO3-N	mg/l	< 15
Pathogen	No./100 mL (*)	Nil
Nematodes	Eggs/L	≤ 1
Faecal Coliform	CFU/100 mL	<200

3.7.3 Implementation Phases

KY WWTP project is planned to serve KY Governorate, thus effluents to be treated at KY WWTP include effluents from Khanyounis City and effluents from Eastern villages. Two horizons are distinguished for KY WWTP:

- Phase 1: Year 2018
- Phase 2: Year 2025.

3.7.4 Influx and Loads

Table 3.4 summarizes the total KY WWTP incoming flows as considered in the Detailed Design.

Table 3.4: The incoming flows for KY WWTP

Parameter	Unit	Phase 1 2018	Phase 2 2025
Average daily flow	m3/d	26656	44948
Average hourly flow	m3/h	1111	1873
Peak coefficient		1.9	1.9
Peak hourly flow	m3/h	2110	3558

Table 3.5 summarizes the total KY WWTP incoming loads as considered in the Detailed Design.

Table 3.5: The design loads for KY WWTP.

Parameter	Unit	Phase 1 2018	Phase 2 2025
BOD5	Kg/d	14247	22399
Total SS	Kg/d	19056	30486
Total Nitrogen	Kg/d	3358	5604
Total Phosphorus	Kg/d	358	605

3.7.5 Infiltration Basins

Infiltration basin will receive treated wastewater from KY WWTP and discharge it to the ground water. Al Fukhari infiltration site has available top area of (97,000 m2) with a trapezoidal shape. The top soil consists of sandy silty clayey layer with thickness between 1 to 5m above clay layer with thickness between 2 to 3 m. Thus; infiltration basins can't be constructed directly on the ground. The clay layer will be excavated an removed from the site, then the basins will be backfilled by suitable soil with high hydraulic conductivity until reach the design level of each basin.

Figure 3.13 Recent photo for Khuza'a (Al Fukhari) infiltration area

The infiltration rates and hydraulic loads for Al Fukhari site is shown in Table 3.6 The loading cycle system that will be taken is to operate 2 days for flooding and 4 days for drying.

Table 3.6 Infiltration rates and hydraulic loads for Al Fukhari site.

year	Average inflow (m3/day)	Hydraulic load (m3/m2/year)	Infiltration rate (m/day)
2010	13,905	75	0.62
2015	21,673	117	0.97
2018	26,664	143	1.19

The hydraulic load of Al Fukhari infiltration basins is sufficient until 2018 (Phase 1).

After 2018, the infiltration area has to be extended to reach the same hydraulic load.

3.8 Agricultural Water Demand

All over the world, the agricultural sector is the dominant user of water by humans, accounting for more than two thirds of withdrawals. In developing countries agricultural use may reach 90% of the total water use, while the remaining portion for domestic and industrial purposes (FAO 92).

During the last fifty years there was a rapid increase in agricultural water consumption and it is expected to continue. Figure 1.4 illustrates the worldwide trend development of agricultural water reuse. Irrigated agriculture in competition with other sectors will face increasing problems of water quantity and quality considering increasingly limited conventional water resources and growing future requirements and a decrease in the volume of fresh water available for agriculture (Kamizoulis, 2004).

3.8.1 Gaza Strip Agricultural Water Demand

Gaza Strip is one of the places where the exploitation level of recourses exceeds the carrying capacity of the environment. This is especially true for the water and land resources, which are under high pressure and subject to sever overexploitation, pollution and degradation.

The municipal water supplied within the Gaza Strip area is recorded monthly while agricultural usage cannot be measured due to the lack of meters, and non-functioning meters on existing wells are being estimated annually. Agricultural water use and water use productivity are not always available at the country level. This is mainly due to the complexity of the assessment methods and to the absence of direct measurement of water withdrawal for agriculture. The Agricultural sector in the Gaza Strip on an average consumes around 75-80 million cubic meters of water annually. All amounts of water used for this purpose come from groundwater wells. Table 3.7 shows the seasonal crop water requirement. It can be noticed that more than two thirds of the total cultivated areas are irrigated areas (118,216 dunums out of the total irrigated area of 154, 821 dunums).

Table 3.7: Irrigation area due to cultivated area in Gaza Stip (MoA ,2010)

Crop	Cultivated Area (dunum)	% of total area	Irrigated Area (dunum)
Vegetables	59,601	36.8%	45712
Horticulture	62,871	38.8%	57339
Field crops	39,066	24.1%	15430
Herbs	50	0.3%	140
Total	161,588	100	118621

The total cultivated areas record in the last years witnessed an observed decline since the mid of the 1900's with a drastic decrease in citrus, the main consumer of water.

While the significance reduction of agricultural lands in the early 2000,s occurred due to the expansion of construction urban areas particularly in Gaza City, the deterioration of irrigation water quality especially in the middle and the southern areas was due to the socio-economic factors and restrictions imposed on the farmers by the Israeli Authorities.(PWA,2012).

3.9 *Agricultural Water Supply*

Khanyounis governorate municipalities (Khanyounis, Bani Suhaila, Abasan Kabira, Abasan Jadidia, Khuza'a, and Qarara) and surrounding villages suffer from real shortage in water supply. Each Municipality in Khanyounis governorate has it own wells, network distribution and operational system therefore the equity of consumption varies from municipality to another either in term of quantity and/or in quality (PWA, 2007b). Concerning the pumped water quality, the chloride ion concentration of the Khanyounis municipality is in the range of 350-1250 mg/l.

Only 2-wells are with chloride of about 350 mg/l and 3-wells are 500-600 mg/l and the remaining 15-wells are 600-1250mg/l. This means that 90% of the wells with chloride exceed the WHO limit (PWA, 2007b). Agriculture consider as a large consumer of water, where the estimates of the Ministry of Agriculture and Palestinian Water Authority that the quantities necessary to meet the requirements of the crops in the area of Khanyounis, about 26 MCM annually. PWA and the MOA depend in the calculation of water consumption of agriculture on crop water requirements (CWR) per year multiplied by the area of each type of crops in the quota allocated to it, Table 3.8 illustrates the total agricultural water consumption in the year 2011, the need for crop water requirements per dunum per annual was estimated according to the experience of MOA.

Table 3.8: Agricultural Water Consumption for the year 2010/2011 at Khanyounis Governorate (MoA ,2011)

Sn.	**Crops**		**Area (dunum)**	**CWR/dunum (m^3/year)**	**TotalCWR (m^3/year)**
1	Horticultural crops	Fruits, Olive, citrus	19,834	600	1,1900,400
2	Vegetables	Irrigated	17,115	700	1,1980,500
3	Green houses	Flowers	7	1500	10,500
4	Field crops		15,590	100	1,559,000
	Total		**52,546**		**25,450,400**

Based on the determination of agricultural areas and the type of crops in the cultivated area, with using the CWR estimation of agricultural crops water consumption from the years 1996 to 2011 (PWA,2013). Figure 3.14 shows the development of water consumption over the years where decreasing and increasing based on the area of cultivated .

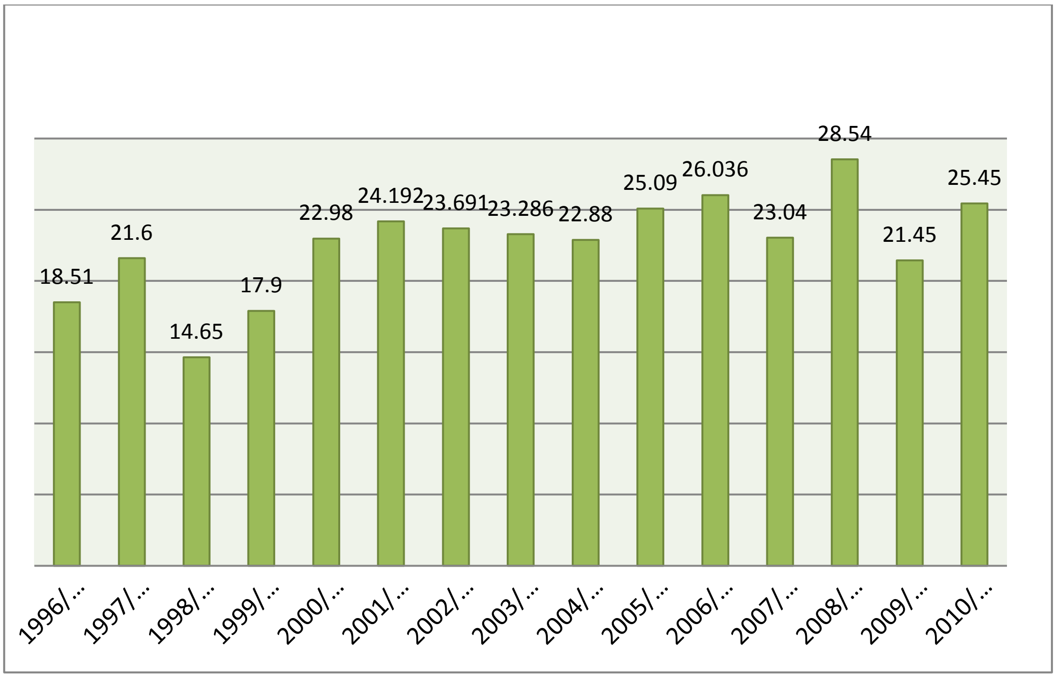

Figure 3.14 : development of water consumption over the years 1992 to 2011 (PWA , 2013)

3.9.1 Agrictural Wells in Khanyounis

According to the MOA and PWA the number of agricultural wells which recorded legally are 423 wells Figure 3.15, while the illegal wells there's no accurate account for them the reports talking about 2300 to 4323 (PWA, 2011; MOA, 2012) this variance and the huge number of agricultural wells weather if the number is 2300 or 4323 wells reflect that PWA have to take strict action to stopped the bleeding of water in terms of quality and quality , the below table for 45 agricultural wells laboratory test was carried over.

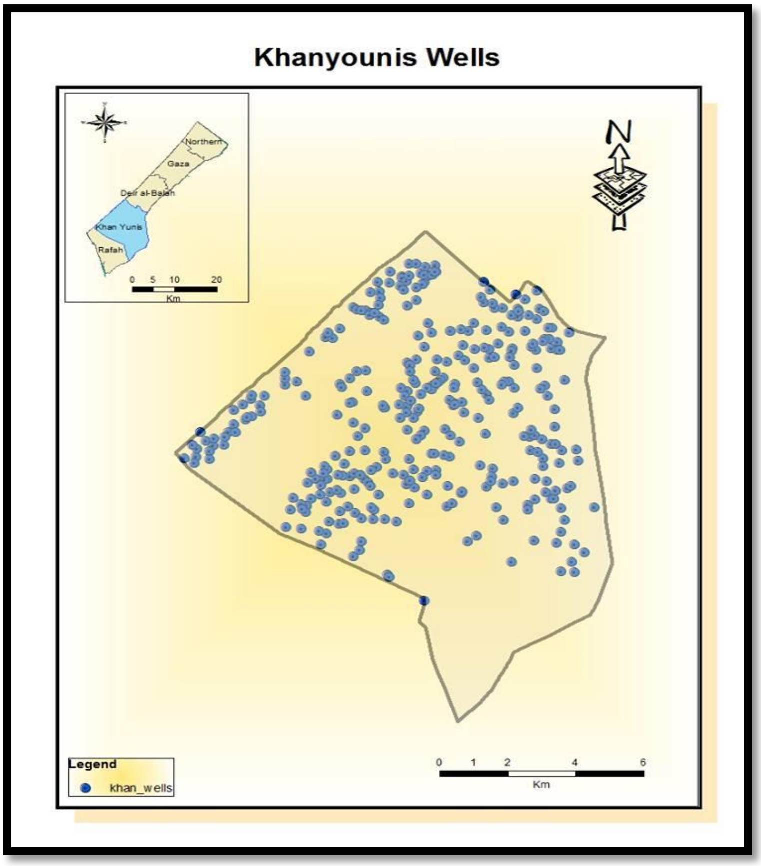

Figure 3.15 Agricultural wells at Khanyounis governorate

Based on PWA and MOA data, water needs for agriculture are calculated based on the crop pattern, land area and water quota allowed for each crop (PWA, 2009). Land use for cultivation purposes considers as an important factor for deterioration of the aquifer due to the amount of water abstraction and infiltration of polluted water. Table 3.9 shows the cultivated area and water demand. It is clear that the total agricultural areas are fluctuating during the period 2002 to 2010 from about

3.9.2

Table 3.9 : development of agricultural land over the years 2002 to 2011 (PWA , 2013)

Year	Gov. Area Donum	2002	2003	2004	2005	2006	2007	2008	2009	2010
Area (Dunum)	116000	54033	51144	58550	54773	63401	55843	57870	58753	44492
Water Consumption in Khanyounis (Mcm)		22.81	24.03	27.45	24.81	25.1	24	23.9	22.6	22

77,900 to 93,500 dunum. Hence, the total water consumption for the irrigation purpose is also fluctuating from about 34.86MCM to 42.25MCM according to crop types and cultivated areas. These quantities of water consumed for agricultural purpose are semi-stable. Although of this water consumption, there are quantities possible to return to the aquifer through the process of irrigation for farmland. Where that 22% can returns to the groundwater. FAO mentioned about 20% to 25% of total quantity of water used for irrigation purposes can be reaching to the groundwater. MOA (1999) estimated the irrigation return flow is about 15% to 30% of total agricultural abstraction.

3.9.3 Quality of Agricultural Water

Ongoing deterioration of the water supply of Gaza Strip poses a major challenge for water planners and sustainable management of the coastal aquifer. The aquifer is presently being overexploited, with total pumping exceeding total recharge. In addition, anthropogenic sources of pollution threaten the water supplies in major urban centers. Many water quality parameters presently exceed World Health Organization (WHO) drinking water standards. The major documented water quality problems are elevated chloride (salinity) and nitrate concentrations in the aquifer (Aish, 2004). Concerning the pumped water quality, the chloride ion concentration of the Khanyounis municipality is in the range of 350-1250 mg/l. Only 2-wells are with chloride of about 350 mg/l and 3-wells are 500-600 mg/l and the remaining 15-wells are 600-1250mg/l. This means that 90% of the wells with chloride exceed the WHO limit (PWA, 2007b).

3.10 Khanyounis Agricultural Practice

Agricultural sector has a wide range of cultivated crops. The main permanent trees are citrus, almonds, guava, apple, date palm, grapes and olives . In addition to wide range of vegetables such as tomato, pepper, eggplants and potato. Rain fed crops such as winter wheat and barley cultivated in winter season only.

3.10.1 Cultivated Area

Area of cultivated land varies in Khanyounis, where there is a clear contradiction and is a big difference between what issued by PCBS 2010 and Ministry of Agriculture-Gaza, where according to a report of PCBS 2010, the cultivated land area of about 29,339 dunum, while the Ministry of Agriculture talking about 48,000 cultivated dunum. The Agricultural land in Khanyounis Governorate are distributed along the governorate on latest data from MOA are 68,251 dunum, from the total area of the governorate 116,000 dunum where 58% of total area as shown in Table 3.10, where the cultivated area with different crops is 48,000 (MOA, 2012). Agricultural land was distributed over all governorate area .

Table 3.10: Cultivated land at Khanyounis Municipalities and other area

S.N	Location	Total area (dunums)	Agricultural area (dunums)
1	Mawassi	8000	7840
2	Al - Mohararat	24,652	10,000
3	Khanyounis city	28,036	16,497
4	Qarara	11,000	6,909
5	Bani Suhaila	7,500	1,873
6	Abasan Jadeda	3,500	1,500
7	Absan Al Kabera	18,000	11,000
8	Khuza'a	4,312	2,812
9	Fukhari	11,000	9,820
	Total	**11,6000**	**68,251**

3.10.2 Crops

The main cultivated land are divided into five categories : Vegetables , Horticulture trees , flowers & medical plants and field crops .

3.10.2.1 Field crops:

Areas cultivated with field crops totaled **25530** dunums in Khanyounis governorate during the 2011/2012 agricultural year: Rainfed field crops made up 22997 dunums (89.9%) while irrigated field crops totaled 2533 dunums (10.1%). The area with the most cultivated crops was 'Abasan al Kabira locality with (31.2%), Table 3.11 show the main field crops in Khanyounis governorate.

Table 3.11: Area of Field Crops and types in Khanyounis Governorate (MoA , 2012)

Sn.	Field Crops type	Area (dunums)	Percentage %
1	Wheat	13650	53.2
2	Barley	4570	18
3	Onions	2500	9.8
4	Potato	4000	16
5	Sweet potato	270	1
6	Lentil	540	2
	Total	**25530**	**100**

3.10.2.2 Horticultural crops

Areas cultivated with field crops totaled **21851** dunum in Khanyounis Governorate during the 2011/2012 agricultural year: Olive trees are cultivated with 12000 dunum, Citrus trees cultivated with 2505 dunum , while Guava and Palm trees are cultivated with 2890 and 2390 dunum respectively as shown in Table 3.12 .

Table 3.12: Area of Horticultural Crops and types in Khanyounis governorate (MoA , 2012)

Sn.	Horticultural crops **type**	**Fruitful-Area (dunums)**	**Un-Fruitful area (dunums)**	**Total area (dunum)**
	Olive	5,600	6,400	12,000
1	Guava	2,860	30	2,890
2	Palm	1,550	840	2,390
	Almonds	145	8	153
3	Grapes	177	270	447
4	Figs	150	30	180
5	Peach	424	70	494
6	Apricot	20	5	25
7	Apples	**467**	**8**	**475**
8	Pomegranate	**145**	**3**	**148**
9	Manga	**140**	**4**	**144**
10	Valncia	53	0	53
11	Shamote	34	20	54
12	Lemon	526	210	736
13	Grapefruit	22	12	34
14	Abo Sura orange	258	120	378
15	Kalamantena **(Makhal)**	950	300	1250
	Total	**13,521**	**8,330**	**21,851**

3.10.2.3 Vegetables crops

Areas cultivated with vegetables crops are **14,537** dunum in Khanyounis governorate during the 2011/2012 agricultural year as shown in Table 3.13

Table 3.13: Area of Vegetables Crops and types at Khanyounis Governorate (MoA , 2012)

Sn.	**Horticultural crops type**	**Area (dunums)**	**Percentage%**
1	Tomato	2,247	15.46
2	Squash	1,380	9.49
	Cucumber	970	6.67
3	Eggplant	630	4.33
4	Green Pepper	720	4.95
5	Paprika	100	0.69
6	Molokhia	140	0.96
7	Watermelon	850	5.85
8	Cantaloup	430	2.96
9	Lettuce خس	10	0.07
10	Beans فاصوليا	420	2.89
11	Beans (لوبيا)	260	1.79
12	Peas - بازلاء	700	4.82
13	Beans -فول	300	2.06
14	Chick-pea- حمص	10	0.07
15	Green Onion	1,800	12.38
16	Spinach سبانخ	310	2.13
17	Chard سلق	**170**	1.17
18	Radish فجل	**270**	1.86
19	Brassica ملفوف	**700**	4.82
20	Okra بامية	**1,105**	7.60
21	Carrots	**140**	0.96
22	Parsley	**150**	1.03
23	Corn	**565**	3.89
24	Squash	**100**	0.69
25	Pumpkin	**50**	0.34
	Total	**14,537**	**100**

3.10.2.4 Medical &Flowers

Areas cultivated with Medical &Flowers are **151** dunums in Khanyounis governorate during the 2011/2012 agricultural year as shown in Table 3.14.

Table 3.14: Area of Vegetables Medical and flowers and types at Khanyounis Governorate (MoA , 2012)

Sn.	Medical &Flowers type	Area (dunums)	Crop ratio %
1	Carnation American	7	4.50
2	Sage	30	20.00
3	Mint	32	21.00
4	Thyme	22	14.50
5	Chamomile	60	40.00
	Total	**151**	**100**

3.10.3 Irrigation methods:

The type of irrigation method selected depends on:

1. Crop type,

2. Soil characteristics,

3. Investment costs of system.

4. Ability of farmers to manage the system.

The common method of irrigation used actually by farmers in the Gaza Strip is surface irrigation which involves complete coverage of soil surface around the tree (small basin) with water. In the recent years using of more efficient irrigation method, like drip irrigation which is relatively expensive, has increased particularly for high price vegetables. The most appropriate efficient methods to be recommended under our conditions are sprinkler and localized irrigation system, which includes bubbler and drippers.

1. Sprinkler systems: Applying of irrigation water in the form of a spray reaching the soil as rain. There are a variety of sprinkler systems including mini-sprinkler (30-80 l per hr.) which is used actually for irrigation of most citrus, olive and fruit trees. Macro-sprinklers can be used to irrigate cereals, fodder crops and industrial crops. Efficiency ranges from 70 to 80%.

2. Localized systems: Water is applied more efficiently in the vicinity of the plant root zone, so that only the root zone gets wet and avoiding overlapping problems. These systems have low energy requirements (1-3 bar) but require high quality of irrigation water in order to prevent clogging problems. Thus good filtration (90- 120 mesh screen or disc filter) unit is required.

2.1 Drip (Trickle) irrigation: Applying water (4-8 l per hr.) continuously through drippers to each individual plant at limited rates. Its efficiency is high (up to 90%) and used for high value crops (vegetables and citrus). Drip irrigation requires clean water without any particles or algae on it. Hazard categories include sand grains, precipitation of carbonates and algae.

2.2. Bubbler irrigation: This system is more recommended as irrigation method for reclaimed water because exit openings are wider than of a dripper and thus less clogging problems. It can be used to irrigate citrus trees under our conditions. The irrigation efficiency is slightly lower than drip irrigation.

3. Sub-surface drip irrigation (SDI): This system is still not enough evaluated through trials under Gaza conditions.

Appropriate irrigation systems for proposed crops:

- Citrus and fruit trees: bubblers, drippers and mini-sprinklers.
- Fodder and grains: macro-sprinklers
- Vegetables and row crops: In-line drippers

The rate of irrigation can be controlled accurately and nutrients can be also added with irrigation water (fertigation).

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CHAPTER

4

Methodology

4.1 Estimation of the Area of Agricultural land

Due to the lack of data and the contradiction in the location, distribution, and the area of agricultural lands along Khanyounis governorate, here database was created for the cultivated land by using ArcGIS 10.1 as a tool to identify the cultivated land with a recent raster image with high quality resolution.

Aerial image can be used as a source of key information on land use. It is almost the most efficient and effective in this area, and remote sensing techniques is one of the important means to scan land cover and land use. This return strongly to several factors, including that they provide the amount of large volume of information for the study area, and this information can be utilized for the purposes of the various studies.

The analysis of data depends on aerial image extracted from Bing-map web site. The photo was taken in December 2011, Arial image shows the details of Khanyounis city and it is used in the distinguishing of the agricultural land, the classification of agricultural land and the determination of the crops types. The crops patterns can be classified into four major categories as follows:

1 - Green Houses

2 - Horticulture Trees

3 – Irrigated vegetables.

4 - Rain-fed crops.

4.1.1 Building the Geodatabase

The study is based on building a database on the ArcGIS software suite and produced by the Environmental Systems Research Institute (ESRI) , which proved to be effective on a global level to get answers more accurate results and earn the trust and the database is created through the following stages:

4.1.2 Physical design of the database

At this stage a database was built to determine the agricultural land in the study area using the interface of Arc-Catalog, where personal geodatabase was setup and data set was created. The coordinate system was defined according to Palestine Grid 1923. Four layers for the study area were created namely, Horticulture trees layer, greenhouses layer, vegetable crops layer, and field crops layer.

4.1.3 Creating and Editing Shape file

This stage is to build shape file where visual discrimination of the types of crops ranging from determining the form of greenhouses as shown in Figures 4.1.c , and also identify land cultivated with horticulture trees and often regularly cultivated been discriminated fruit trees (large) trees (small) as the satellite image Figure 4.1.a , as well as cultivated land have been identified with vegetables through Figure 4.1.b, and either of the remaining lands are uncultivated lands have been cultivated as rain-fed crops Figure 4.1.d.

a) Horticultural crops

b) Vegetables

c) Green houses

d) Rain-fed crops

Figure 4.1 : Aerial Satellite image a) Horticultural crops, b) Vegetables, c) Green houses & d)Rain fed crops.

4.1.4 Auditing and verification

In certain situations, the interpretation of aerial image is difficult and confusing. It's difficult to determine what crops cultivated in that territory. To make sure several places where physically inspected by field visit to cultivated areas. Five different places were visited in the Khanyounis governorate of the Eastern territory of Khuza'a and Abasan and Bani Suhaila and also the western territory of the governorate where the Mawasi lands and Al-Mohararat. During the field visit a matching between implanted on the ground and the aerial image and the results were most of places identical.

As mentioned before a verification visit to the agricultural lands has been made to Al-Fukhari area and Al-Mohrarat area . Interviews with farmers in that territory for the purpose of identification of cultivated land and knowing the types and quantity of crops and what are water quantities needed for irrigation.

Agricultural land at Al-Fukhari is farmed by the citizen Abu teama. The total land area of about 100 dunum , which are located within border line between the Gaza Strip and the occupied territories, general view for the agricultural land is shown in Figure 4.2, and through -deep interview with the farmer, he informed us that the planted land in summer in the range of 50 dunum, while in winter 100 dunum is cultivated. The agricultural land area in summer is smaller than in winter because of the scarcity of water in summer and in winter the majority of the land are cultivated with rain-fed crops depending mainly on rain water. The most important agricultural crops in the spring , summer and autumn crops are vegetables such as potatoes, cauliflower, tomatoes and peppers .

Figure 4.2 General view for Abu Teama Agricultural land illustrating the type cultivated crops

4.1.5 Calculation of Agricultural area

After complete editing all polygons in all layers, estimating the area of each layer represents the types of which summarized in Table 4.1

Table 4.1: estimated area for cultivated land for Khanyounis governorate from Raster image

Sn	Crops type	Area (dunum)	Percentage %
1	Green Houses	2513.95	4.05%
2	Irrigated vegetables crops	12530.09	20.25%
3	Horticulture Trees	21400.79	34.50%
4	Rain- fed crops	25500.60	41.20%
	Total	**61945.43**	**100.00%**

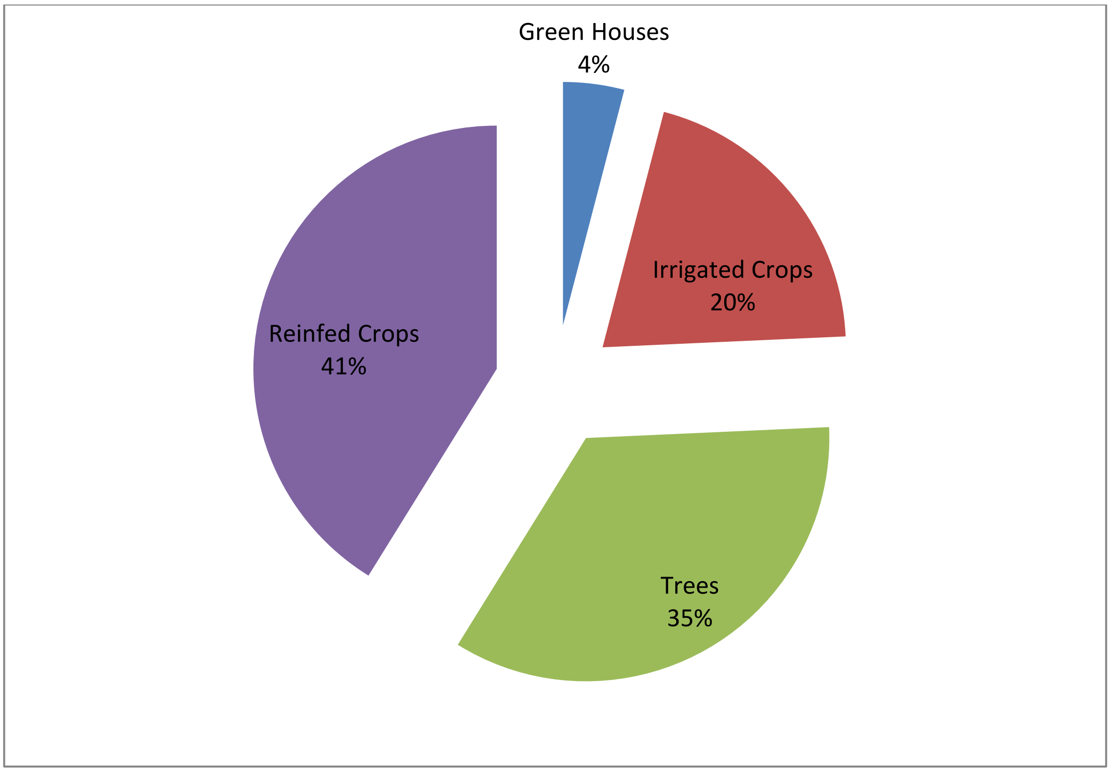


Figure 4.3 Agricultural crops at Khanyounis governorate .

Table 4.1 shows that the area of Agricultural land which is cultivated with greenhouses equals 2,514 dunums which is equivalent to 4.05% of the total agricultural land. The area of land cultivated with irrigated vegetables equal to 12,530 dunums, which accounted for 20.25% of the total cultivated land. The area of land planted with trees equal 21,400 dunums which is 34.50%, and finally land cultivated with rain-fed field crops equal to 25,500 dunums which is 41% of the total agricultural land in the governorate.

4.1.6 Distribution of Agricultural crops

Through the map that have been developed by software ArcGis, It was found that the agricultural land are irregular distributed over all the governorate. The population mass is concentrated in the center of the governorate and mainly in Khanyounis city as illustrated in Figure 4.4.

Accordingly to the agricultural land , it is found that the coastline of the governorate Al-Mawasi area are mostly cultivated with vegetables as shown in Figure 4.5, fruit, trees in the northern parts of the Mawasi area, (citrus , olive and fruit) Figure 4.7. Recently, according to the plan of the Ministry of Agriculture, thousands of dunums in Al-Mohararat area was planted with fruit trees because of availability of water in this region with high quality.

In the Eastern part of the governorate field crops are cultivated that depend on rainwater in winter due to the lack of groundwater in this region but in summer vegetables are cultivated through the process of the transfer of water from the center of the governorate Figure 4.6. Several wells have been drilled in this region and then the water are pumped across the water networks that created by farmers.

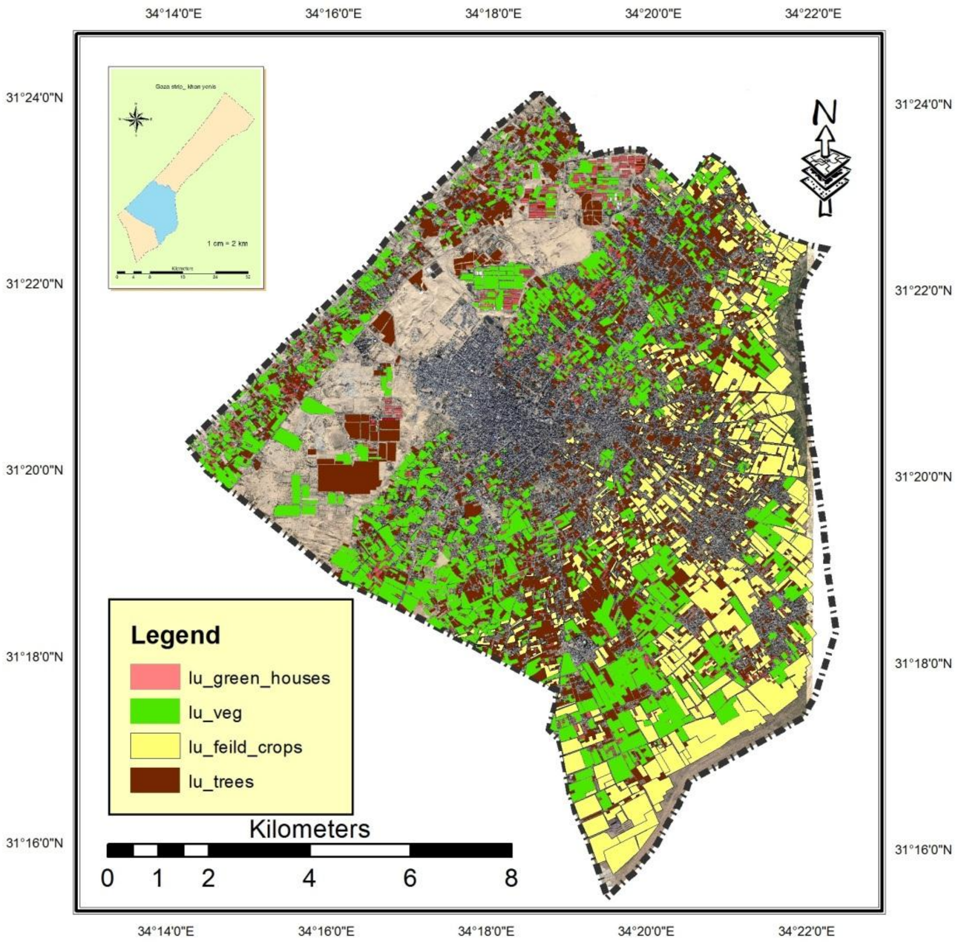


Figure 4.4 Output of GIS map satellite image with different agricultural crops at Khanyounis governorate (prepared by the researcher)

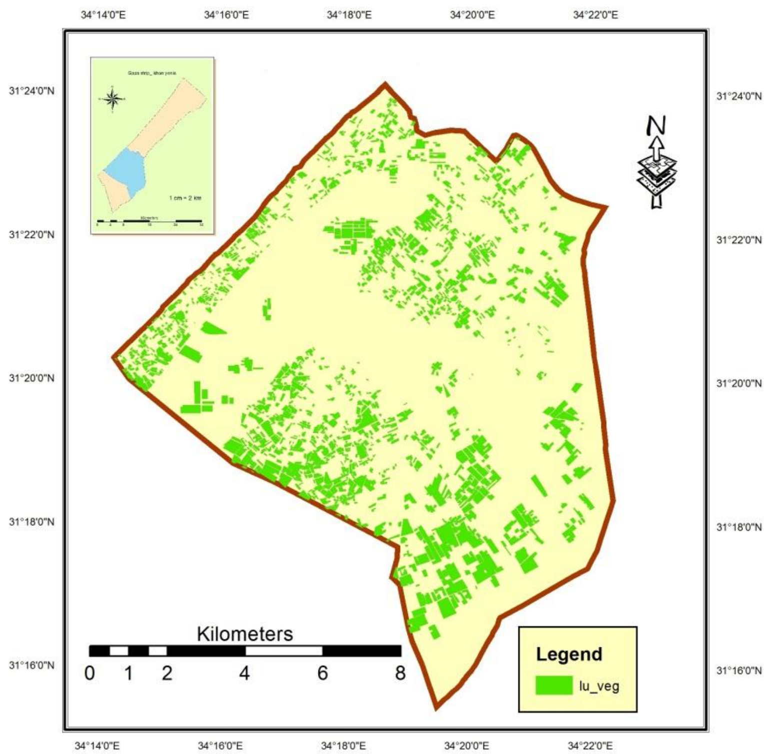


Figure 4.5 Distribution of Vegetables through Khanyounis governorate (prepared by the researcher)

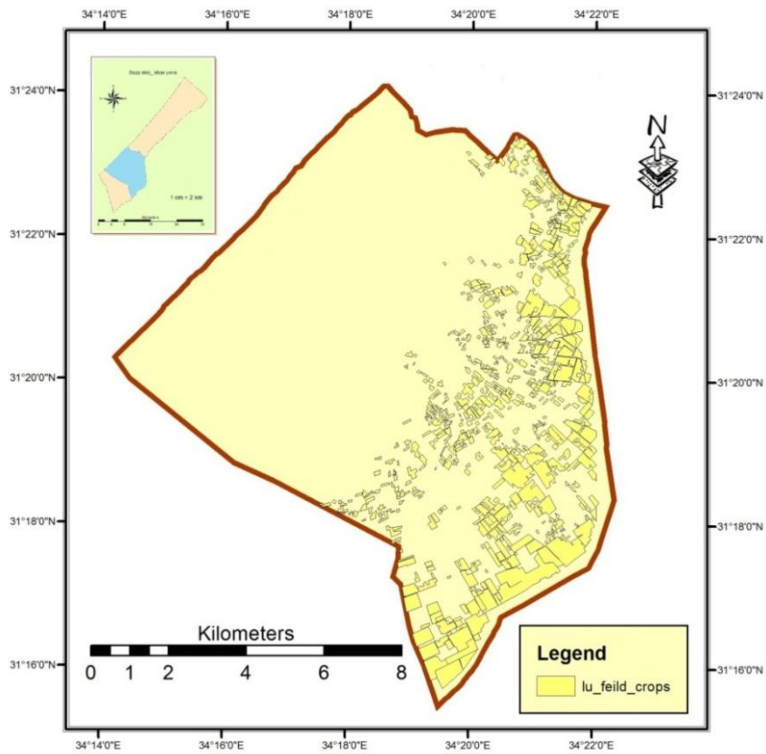
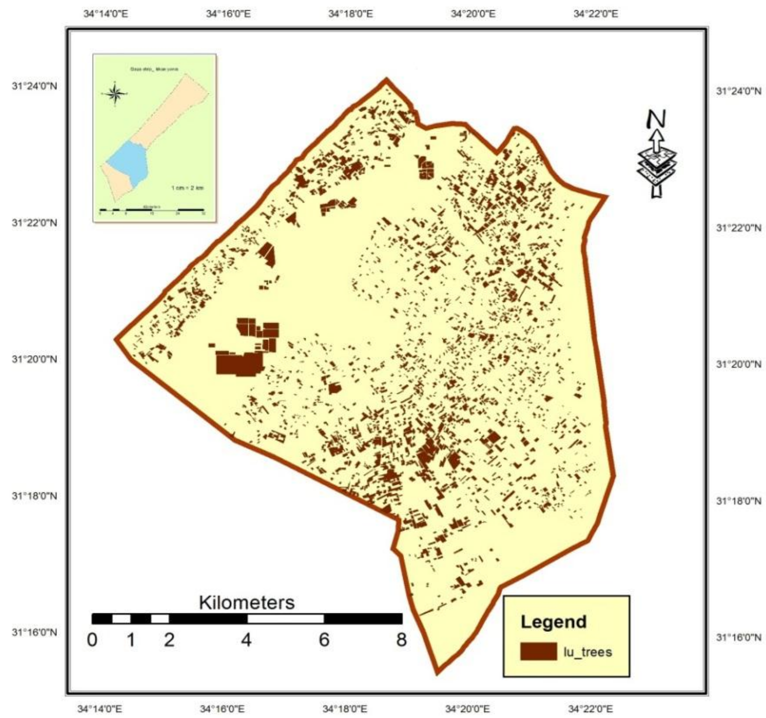


Figure 4.6 Distribution of field crops through Khanyounis governorate (prepared by the researcher)



4.7 Distribution of orchards through Khanyounis governorate (prepared by the researcher)

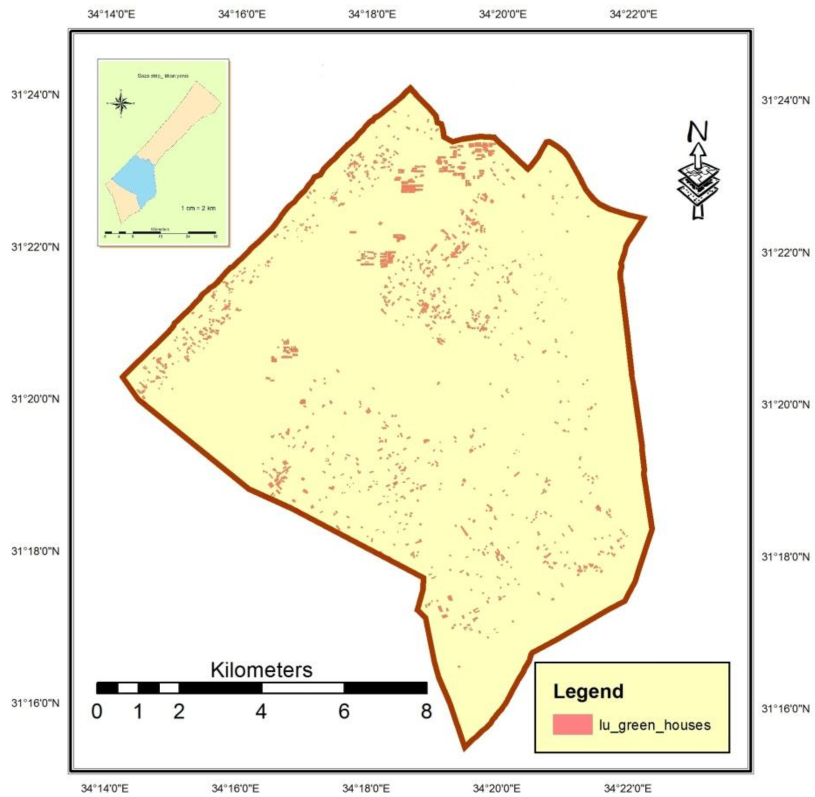


Figure 4.8 Distribution of greenhouses through Khanyounis governorate (prepared by the researcher)

4.2 Crop Water Requirements

The water requirements for the different crops were calculated using local climatic parameters. Crop coefficients were obtained from FAO Irrigation and Drainage Paper No. 33. The net irrigation requirement for crops was calculated using crop evapotranspiration (ET) and effective rainfall according to Cropwat V.8, 2009.

The irrigation water demand was determined based on the following factors:

- Type and percentage of crops in the project area.
- Climate in the project area (rainfall, temperature, relative humidity, etc.) taking the
- climate changes in consideration.
- Soil characteristics as given in the attached agricultural soil testing report.
- Irrigation methods.

Monthly Crops Water Requirements (mm) using Cropwat model are summarized in Table 4.2

Table 4.2 Monthly crops water requirements (mm) using Cropwat model

Month	Citrus	Olives	Palm	Fruits	Vegetables
Jan	0	0	7.1	3.1	8.7
Feb	10.9	0	26.9	4.2	17.2
Mar	48.7	16.8	68.3	18.1	58.3
Apr	89.3	52	106.8	48.6	113.4
May	116.1	72.1	130.5	68.9	142.3
June	125.3	75.8	137.8	81.5	147.5
July	140.4	78	154.2	96.5	135.6
Aug	140.2	81.8	154	98.9	78.1
Sept	121.8	75.2	133.9	78.4	69.3
Oct	78.8	45.2	93.6	57.6	82.0
Nov	37.2	18.8	54	33.5	57.8
Dec	6.5	0	24.4	2.1	10.6
Total	**915.2**	**515.7**	**1091.5**	**591.4**	**920.8**

4.2.1 Leaching requirements

The leaching requirement is the ratio of the net depth of leaching water to the net depth of water which must be applied for consumptive use. Calculating the leaching requirement for trickle irrigation is greatly simplified by:

$$LR = \frac{ECw}{ECd} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.1)$$

Where:

ECw = Irrigation water salinity, dS/m

ECd = Drainage water salinity, dS/m

ECd can equal 2 (max ECe) Then LR can be calculated for trickle irrigation percent as:

$$LR = \frac{ECw}{2max\ ECe} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.2)$$

Where:

Max ECe = electrical conductivity of the saturated soil extract that will reduce crop

yield, to zero, dS/m. (Sprinkler and Trickle Irrigation by Bliesner and Keller, 2001) However, for sprinkler and surface irrigation systems, leaching requirement calculated using the following equation:

$$LR = \frac{ECw}{5ECe - ECw} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.3)$$

Where ECe is estimated electrical conductivity of the average saturation extract of the soil root zone profile for an approximate yields reduction, dS/m.

Table 4.3 illustrates Leaching requirement (ratio, %) Drip, sprinkler and surface irrigation systems.

Table 4.3 Leaching requirement (ratio, %)

Crop	Citrus tress	Olive trees	Vegetables	Fruit trees
ECw , dS/m(1)	2.92	2.92	2.92	2.92
ECe , dS/m(2)	2.3	3.8	3.4	2.3
Sprinkler and surface irrigation systems , LR. %	34	18	8.6	34

Based on recommended cropping pattern, recommended irrigation system for each crop, average leaching requirement will be 25% at average.

For the purpose of estimating the gross water requirement for each crop, irrigation efficiency (Ei) of 80% was assumed for good irrigation system management. Since leaching fraction more than 10% then gross irrigation is calculated using the following equation:

$$Gross\ Irrigation\ = \frac{0.9\ Net\ Irrigation}{(1 - LR)(\frac{Ei}{100})} \ldots\ldots\ldots\ldots\ldots..(4.4)$$

(0.9) in Equation 4.4 is include to account for the unavoidable deep percolation losses which normally will satisfy approximately 10% of the leaching need. Table 4.4 shows the gross irrigation water demand for the proposed calculated crops.

Table 4.4 Gross irrigation water demand for the proposed calculated crops.

Crop	Net Irrigation m3/dunum/year	Gross Irrigation m3/dunum/year
Citrus	915.2	1372.5
Olive	515.7	613.5
Fruits	591.4	887.1
Vegetables	920.8	1381.2
Palm	1091.5	1637.25

4.3 WEAP Model

WEAP is a microcomputer tool for integrated water resources planning. It provides a comprehensive, flexible and user-friendly framework for policy analysis. A growing number of water professionals are finding WEAP to be a useful addition to their toolbox of models, databases, spreadsheets and other software. (WEAP Tutorial 2012). WEAP, the Water Evaluation and Planning software is intended to be an effective tool for integrated water resource management (IWRM). The design goals were that it be useful to planners, easy to use, affordable, and readily available to the broad water resource community. WEAP is designed around a water accounting and allocation framework that balances demand and installed infrastructure. It also allows for hydrologic processes to be incorporated in models using a lumped-parameter hydrologic model. As a planning tool, WEAP supports scenario analysis as part of its core features. Examples of possible scenario variations include alternate water supply and demand options, climate scenarios, and changing land use. WEAP's strength is addressing water planning and resource allocation problems and issues (Yates et al. 2005). WEAP has been enhanced so that it is relatively easy to link MODFLOW groundwater models and QUAL2K water quality models to a WEAP model. As discussed below, most of the calculations in WEAP are carried out automatically within a water allocation framework. In addition, WEAP offers spreadsheet-like capabilities for implementing algorithms. Finally, WEAP models are extensive in other ways as well, e.g., by linking to dynamic link libraries, or DLLs, and can be combined with other models.

WEAP aims to incorporate these values into a practical tool for water resources planning. WEAP is distinguished by its integrated approach to simulating water systems and by its policy orientation. WEAP places the demand side of the equation - water use patterns, equipment efficiencies, re-use, prices and allocation - on an equal footing with the supply side - streamflow, groundwater, reservoirs and water transfers. WEAP is a laboratory for examining alternative water development and management strategies.

WEAP is comprehensive, straightforward, and easy-to-use, and attempts to assist rather than substitute for the skilled planner. As a database, WEAP provides a system for maintaining water demand and supply information. As a forecasting tool, WEAP simulates water demand, supply, flows, and storage, and pollution generation, treatment and discharge. As a policy analysis tool, WEAP evaluates a full range of water development and management options, and takes account of multiple and competing uses of water systems.

WEAP is an appropriate tool for the present study for several reasons. First, it is available at no charge for institutions in developing countries and at an affordable price for developed countries and private companies. Second, the scenario features of WEAP support the exploration of how non-traditional water sources could change water availability and use in the targeted area. Finally, because WEAP models are easily extendible, the model that is built within this research project could be used as the basis for a larger model that includes the whole of G.S. The PWA can integrate groundwater models and water quality variables into the WEAP model if necessary.

4.3.1 WEAP Development

The Stockholm Environment Institute provided primary support for the development of WEAP. The Hydrologic Engineering Center of the US Army Corps of Engineers funded significant enhancements. A number of agencies, including the World Bank, USAID and the Global Infrastructure Fund of Japan have provided project support. WEAP has been applied in water assessments in dozens of countries, including the United States, Mexico, Brazil, Germany, Ghana, Burkina Faso, Kenya, South Africa, Mozambique, Egypt, Israel, Oman, Central Asia, Sri Lanka, India, Nepal, China,South Korea, Thailand, Jordan, Syria, Lebanon, Iran, and Greece. (WEAP Tutorial 2012).

4.3.2 The WEAP Approach

The model functions on the principle of water balancing. Since the first version of the model was developed in 1990 the model has been applied in a lot of research work. It has been applied primarily in a number of studies concerning;

• Agricultural systems

• Municipal systems

• Single catchments or complex Trans-boundary river systems

WEAP can address a wide range of issues, e.g., sectoral demand analyses, water conservation, water rights and allocation priorities, groundwater and streamflow simulations, reservoir operations, hydropower generation, pollution tracking, ecosystem requirements, vulnerability assessments, and project benefit-cost analyses.

4.3.3 Model Structure

The structure of the model is such that, the water resource system is represented in terms of groundwater, reservoirs withdrawal, transmission and wastewater treatment facilities; ecosystem requirements, water demands and pollution generation. The analyst can choose the level of complexity to meet the requirements of a particular analysis. This customization can also be used to reflect the limits caused by restricted data (Sieber et al, 2005). The model consists of five main views:

Schematic

The study area is defined in the schematic view. It is a GIS based tool which allows vector or raster layers to be imported and used as background layers. Its uses a drag and drop method in which objects such as demand nodes, reservoirs, groundwater supply, etc can be positioned. This allows for changes and modifications to be made in the area with ease. A sample of the schematic view is shown in Figure 4.9.

Data

The data view is where data is entered into the program. It allows variables and various assumptions to be created using mathematical relationships. Data can also be imported from Excel.

Result

Results are easily accessed. Every model output is displayed. This can also be exported to Excel for further modification.

Scenario Explorer:

You can highlight key data and results in your system for quick viewing.

Note:

Notes can be added to the model for documentation of the key assumptions.

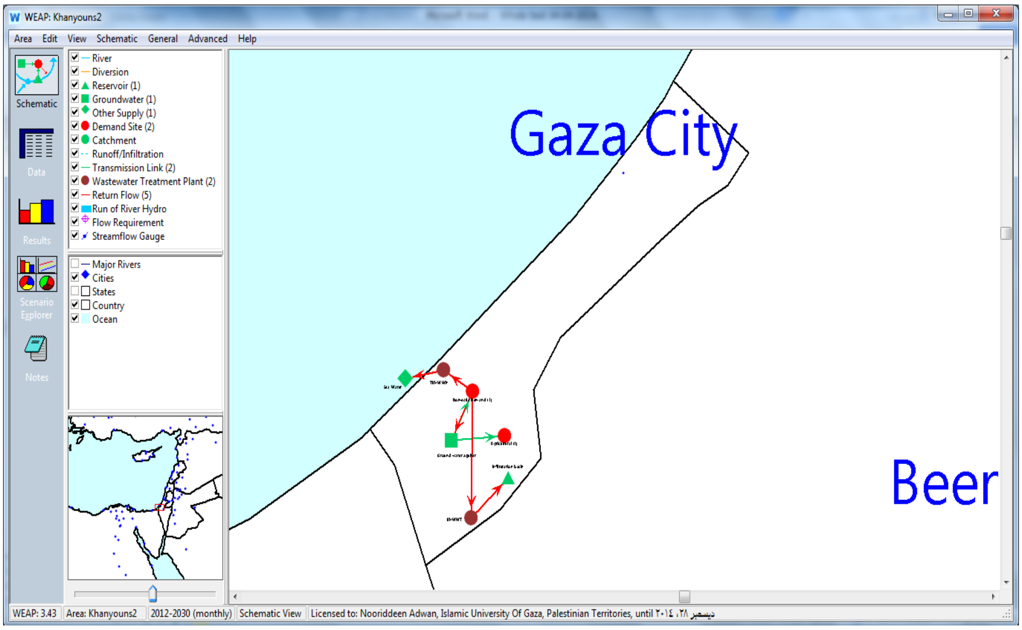


Figure 4.9 Schematic view of WEAP model showing the various nodes.

4.3.4 Modeling Process of WEAP

The modeling of a watershed using the WEAP consists of the following steps (Levite, 2003).

- Definition of the study area and time frame. The setting up of the time frame includes the last year of scenario creation and the initial year of application.
- Creation of the Current Account which is more or less the existing water resources situation of the study area. Under the current account available water resources and various existing demand nodes are specified. This is very important since it forms the basis of the whole modeling process. This can be used for calibration of the model to adapt it to the existing situation of the study area.
- Creation of scenarios based on future assumptions and expected increases in the various indicators. This forms the core or the heart of the WEAP model since this allows for possible water resources management processes to be adopted from the results generated from running the model. The scenarios are used to address a lot of "what if situations", like what if reservoirs operating rules are altered, what if groundwater supplies are fully exploited, what if there is a population increase. Scenarios creation can take into consideration factors that change with time.
- Evaluation of the scenarios with regards to the availability of the water resources for the study area. Results generated from the creation of scenarios can help the water resources planner in decision making.

The major components of the water delivery system shown in Figure 4.10 have been represented in the WEAP software model for water allocation and planning.

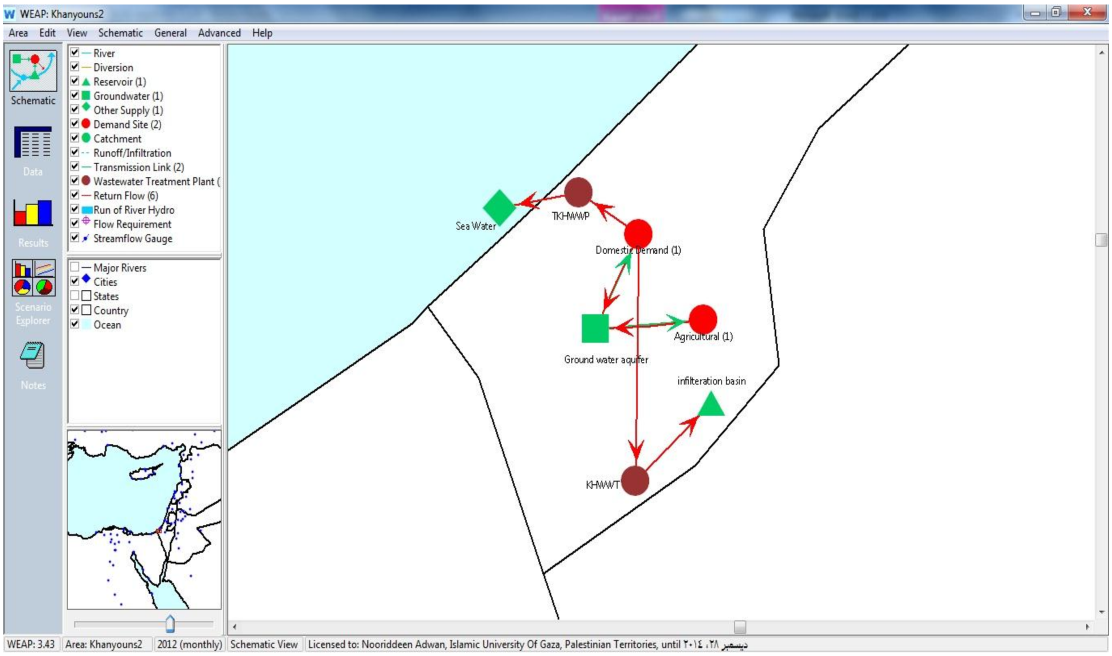


Figure 4.10 Study area represented in WEAP.

In designing the schematic representation of the study area in WEAP, the objective was to include as much detail as was needed to properly characterize both demand and supply sources, subject to the availability of field data. The representations consist of the following main elements:

Distribution Systems: A distribution system represents water users in a common geographic area with shared water sources. In the current representation, distribution systems are identified either with irrigation systems or municipal demands the same categories used by the MWI for allocating water in Khanyounis governorate. The water demand in each distribution system for Khanyounis governorate is aggregate, while irrigation demand is partitioned by crop type, cultivated area and crop demand. Within WEAP, distribution systems are represented by demand sites.

Municipal water demands are estimated as described in the previous section. Irrigation demands are estimated by multiplying the area under different crops by an assumed irrigation rate.

4.4 Demand Scenarios:

In this section the demand was projected in the model for the purpose of forecasting and management, which could help in analyzing various scenarios output as variations, uncertainty and sources of risk.

The model uses the term “annual activity” Figure 4.11 which means the annual demand represents the amount of water required by each demand.

As explained above, the model takes into account two types of demand: domestic (urban presented by Khanyounis municipalities) and agricultural demand. For domestic demand in the period 2012-2030. In the scenario we assumed continued growth at 3.5% per year.

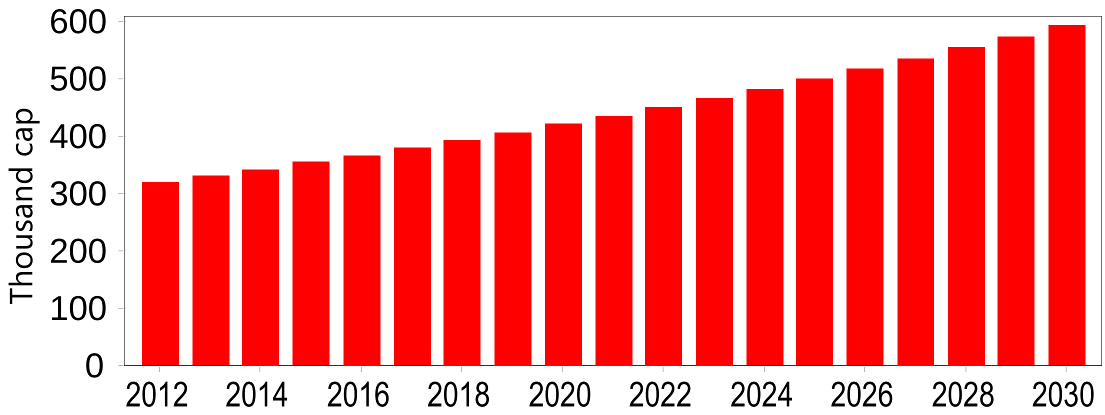


Figure 4.11: Annual water requirement for population growth in Khanyounis governorate

For agriculture all scenarios assumed a small increase in the cultivated area. This was considered to be reasonable given the limited water resources in the Gaza strip. The change in agricultural area is shown in the Figures 4.12., 4.13and 4.14.

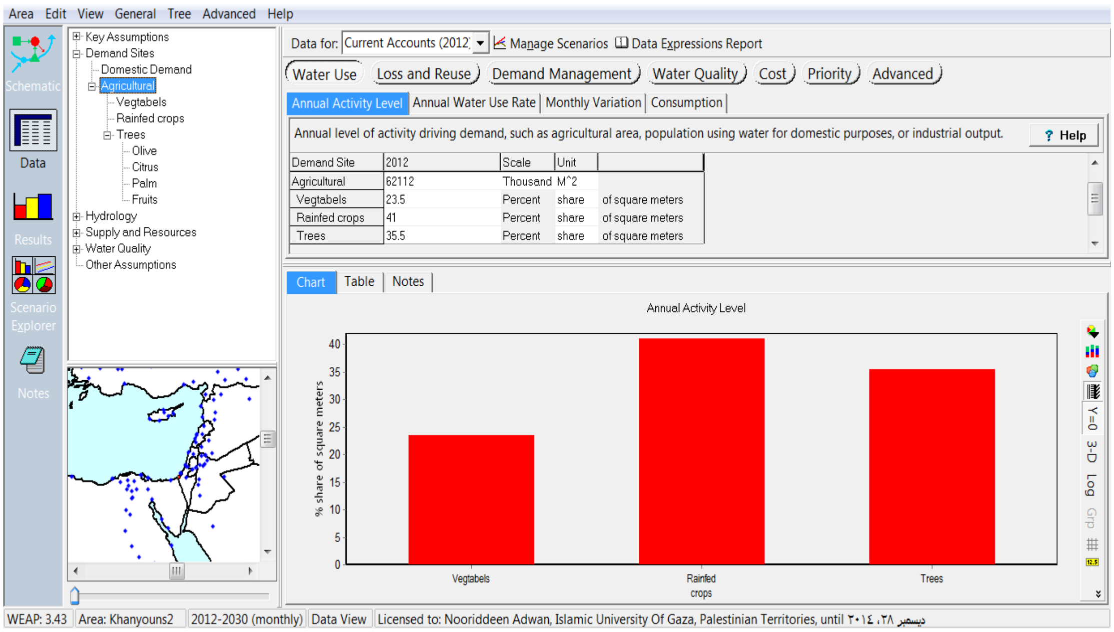


Figure 4.12 : Three main categories' of Agricultural land in Khanyounis governorate

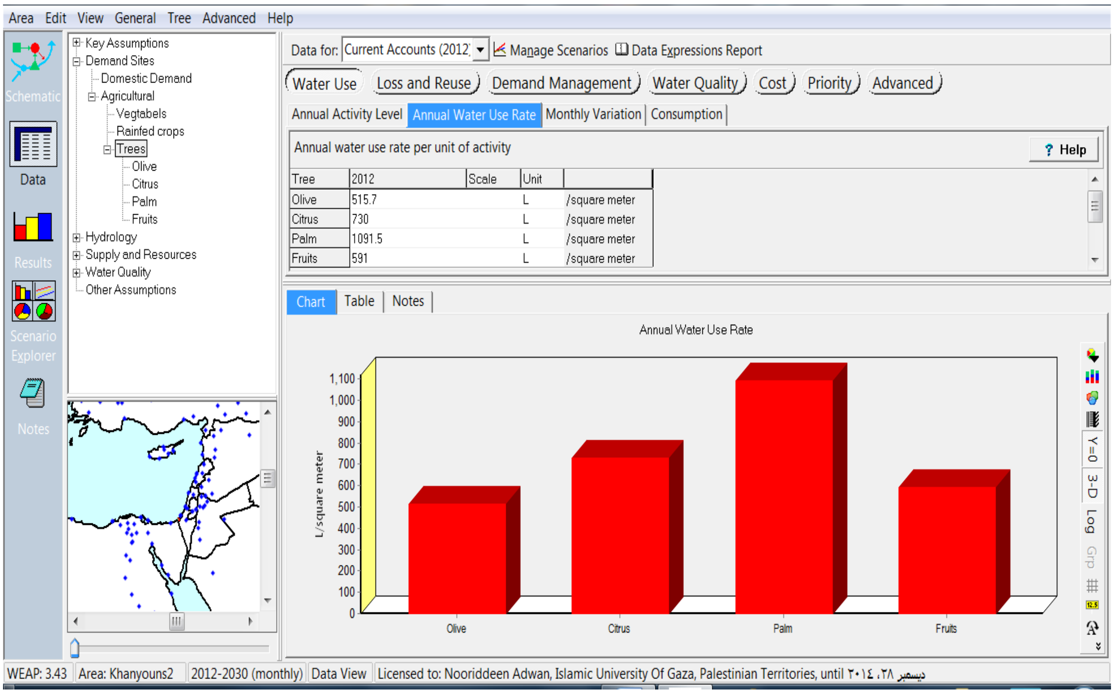


Figure 4.13: Type of tress and CWR for each type

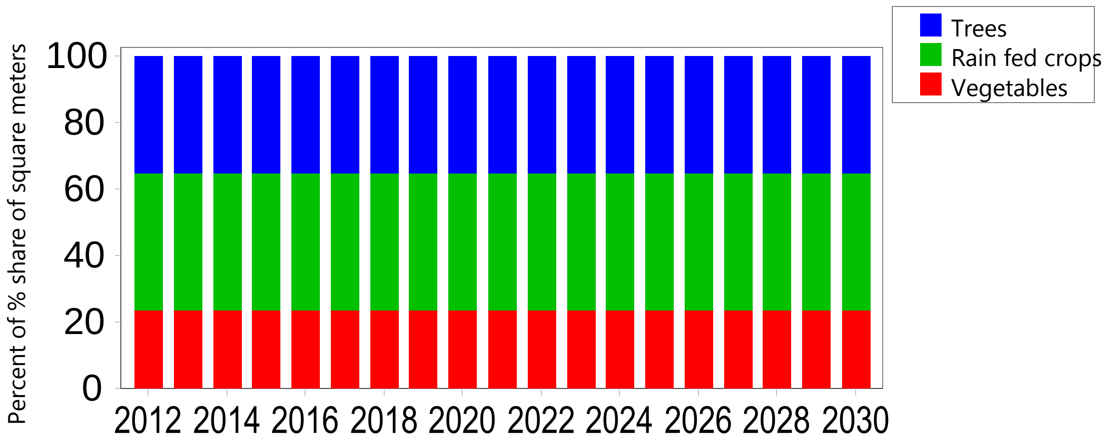


Figure 4.14 Annual water requirement for projecting agricultural demand in Khanyounis governorate

4.5 Scenarios Development

The study will evaluate water management options for Khanyounis Governorate using WEAP. This model will help to identify management options under different scenarios which in turn will help as a decision support tool to identify the best options concerning water management in Khanyounis governorate. The following scenarios represent the most important water management options that will be developed and analyzed in this study:

1. Business As Usual Scenario (BAU) .
2. Change Crop Pattern of agriculture.
3. Using Treated Waste Water.
4. Integration between scenario 2 &3 .

A scenario approach is a useful technique for water sustainability assessment, as it allows a wide view over a long time horizon that considers futures with fundamentally different development and environmental assumptions and policies. This section evaluates different scenarios that were tested by the WEAP model to support planners in their water allocation decisions. The projected year for the scenarios was 2030. Based on a variety of economic, demographic, hydrological, and technological trends a "reference" or "business-as usual" scenario projection was first established and called the Reference Scenario. Then three alternative scenarios were developed with different assumptions about future developments. These scenarios were: Business-as-Usual, using treated wastewater, changing crop pattern, combining the reuse of TWW with changing crop patterns of agriculture.

Scenario analysis aims to answer "What if…?" questions. Data are essential to evaluate the current and past situation, while models are indispensable in exploring options for the future.

4.5.1 Business As Usual (Zero Scenario)

- **Description of Scenario**

The business as usual scenario is the base scenario that extrapolates historical trends to provide a baseline for the studied period. The objective of a reference scenario is to help in learning what could occur if the current trend continues and to understand the opportunities, pressures, and vulnerabilities that this might bring.

This scenario is based on the assumption that the irrigated land and water use efficiency will follow the same trend as in the last ten year. There will be no major change in prevailing agriculture practices.

The main features of the this scenario are :

- Population growth rate used is 3.5%
- Per capita water demand 120 l/d.

4.5.2 Using Treated Wastewater

- **Description of Scenario**

Treated wastewater is a viable source of alternative water for agricultural production in water deficit regions. Use of treated wastewater can reduce the stress on freshwater supplies and enhance recovery of affected aquifers due to reduced abstraction. In coastal regions such as Gaza strip , where significant deterioration of freshwater quality due to seawater intrusion is already occurring, the use of treated wastewater in agricultural production can save freshwater resources. However, water allocation for agricultural production using treated wastewater should be conducted in a responsible manner by considering the potential impacts on public health due to pathogens in treated wastewater.

Although treated wastewater is readily available in Gaza, very little work has been conducted to evaluate the potential use of treated wastewater in agriculture to reduce stress on fresh water supply and enhance aquifer recovery.

At present, the Khanyounis area is not served by any wastewater treatment plant. Most of the collected wastewater is currently transported to the western lagoons, which have been constructed in 2008 in the western part of the city (close to the sea). The current wastewater discharge system is considered as temporary emergency system and the environmental situation is in danger including groundwater, soil and marine environment. The unconnected to sewerage system areas of Khanyounis Governorate especially the eastern villages are depending on the cesspits and or septic tanks for wastewater disposal.

Since 2004, around 60% of residents of Khanyounis city have being connected to sewage collection networks established in central parts of the city. In year 2025, 83% of residents of Khanyounis city are expected to be served by sewer system in addition to 63% of residents of the eastern villages.

Due to absence of a waste water treatment plant, the collected raw sewage is diverted to four temporary collection lagoons established in 2008 in the sand dunes in the western side of Khanyounis city; that were expanded to six ones in 2013. These lagoons are currently discharging more than 12,000 cubic meters per day of partially treated waste water to the Mediterranean Sea.

The UNDP/PAPP has been entrusted by the Government of Japan and by the Kuwait Fund for Arab Economic Development through the Islamic Development Bank and by UNDP with a co-financed fund for the implementation of the project "The Construction of Khanyounis Waste Water Treatment Plant". The Project's strategic plan was developed by designing an extendable waste water treatment plant to serve population of Khanyounis Governorate up to year 2025, while constructing it into two Phases reference to available resources. The design of KY WWTP, Phase I is based on flow of 26,600 cubic meters per day, while the design figures of Phase II is based on flow of 44,900 cubic meters per day.

The treated water quality requirements are summarized in Table 4.5 as defined in the detailed design assignment of the treatment plant.

Table 4.5: Treated wastewater quality requirement of the plant

Parameter	Unit	Required effluent quality for KY WWTP
BOD5	mg/l	< 20
Suspended solids, SS	mg/l	< 15
Total nitrogen	mg/l	< 25
Ammonium nitrogen, NH4-N	mg/l	<10
Nitrate nitrogen, NO3-N	mg/l	< 15
Pathogen	No./100 mL (*)	Nil
Nematodes	Eggs/L	≤ 1
Faecal Coliform	CFU/100 mL	<200

4.5.3 Changing Crop Pattern Scenario

- **Description of Scenario**

Cropping patterns were designed by integration of soil type and irrigation water availability to improve irrigation sustainability. In Gaza Strip Olive farms have been encouraged by the Ministry of Agriculture who introduced high quality varieties.

The Olive tree has low water consumption and is potentially a highly profitable crop. This makes it an attractive alternative crop both to traditional crops with lower profitability and other highly profitable crops with potentially higher water consumption such as citrus and Palm.

This scenario assumed changed patterns of agriculture in which total Olive tree cultivation was expanded and that of Palm and citrus were reduced. The range of these changes as describe in Table 4.6 for the option I increase the olive orchards to 15,700 and reduce the area of palm, fruits and citrus to 1500,1500, and 3451 dunum respectively . In option II no cultivation for palm and fruits and reduce citrus to 1200 dunum only . In option III reduce the area of vegetables to 10,000 dunum and depend on the rain-fed crops to be increase to 39,918 dunum.

Table 4.6 Scenario 2 , with 3 option of changing crop pattern

Orchards trees	Existing Total area (dunum)	Option I	Option II	Option III
Olive	12000	15700	12000	12000
Palm	2390	1500	0	0
Fruits	4956	3451	0	0
Citrus	2505	1200	1200	0
Vegetables	14537	14537	14537	10000
Rain-fed crops	25530	25530	34181	39918
Total	61918	61918	61918	61918

4.5.4 Combination Scenario 2 & 3

- **Description of Scenario**

In this scenario we will combine between two scenarios; using treated waste water and changing the crop pattern, where the expected extracted quantities (26,400 ,44,900) m^3/day from surrounding wells around the infiltration basins in 2018 and 2025. These quantities especially are to be used in irrigation for different options of scenario of changing crop pattern only for orchards tress like olives, citrus, fruits, and palm trees. Also this scenario assumed to shift theses orchards to the eastern side of the governorate near the infiltration basins for saving the cost of transferring and carrying out treated waste water for long distance through the governorate which need new networks.

CHAPTER

5

Results & Discussion

5.1 *Scenario Analysis and Results*

5.1.1 Results of Scenario 1

- **Domestic and Agricultural demand**

The following graphs were directly obtained from the WEAP software and were exported to Excel. Figure 5.1 shows that the demand for Khanyounis governorate is increasing over time due to an increase in population while the agriculture demand remains almost constant due to the fact that the agricultural area is restricted and cannot be extended. The demand of Khanyounis governorate illustrated in this scenario reaches around 45,91 MCM annually subdivided into 21.70 for domestic demand and 24.21 MCM for Agricultural demand .

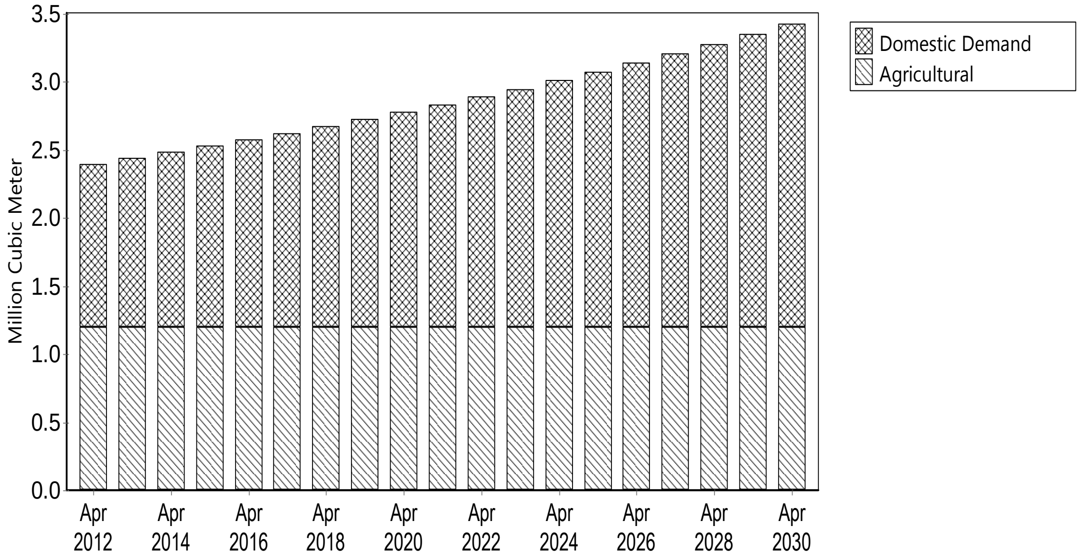


Figure 5.1: Domestic and agricultural demand for Khanyonuis governorate up to 2030 under Scenario 1.

- **Water Balance**

Based on the estimates of water inputs and outputs of the aquifer system, a water balance during (2006 -2010) of the coastal aquifer in the study area has been developed. Table 5.1 shows the water balance. Thus, it can be observed that there is a deficit of water in the period (2006-2010) is 23.5 MCM. The outflow quantity (water abstraction) from the aquifer in the stage (2006-2010) reach to 13.40 MCM. While water consumption for irrigation purposes by agricultural wells is twice the quantity of the municipalities' abstraction. The following factors that may affect the deficit quantity are: Natural factors; which is represented by the climate changes and precipitation rate.

Table 5.1 Water balance for scenario No.1

Water Balance		**(2006-2010)**	**(2030)**
Inflow (MCM)	Infiltrated Rainfall	7.9	8.1
	Return Flow	5.2	5.5
	Lateral Inflow	4.0	4.0
Net Ground Inflow (MCM) =		17.1	17.6
Out Flow (MCM)	Municipal	13.4	21.7
	Agricultural	23.5	24.2
Net Ground Water outflow (MCM) =		36.9	45.9
Net Balance – deficit (MCM) =		-23.5	-28.3

The deficit in the water balance will be increased over the time to reach in 2030 to 28.30 MCM.

- **Storage Ground Water**

Due to continuous abstraction from the ground water aquifer WEAP can explore the storage of ground aquifer among the period of scenario until 2030. It's clear there's a decreasing in the quantity of fresh water this decreasing already will be substitute by sea water which increasing the sea water intrusion , Figure 5.2 show the decrease rate of fresh water storage up to year 2030 under Sc.1

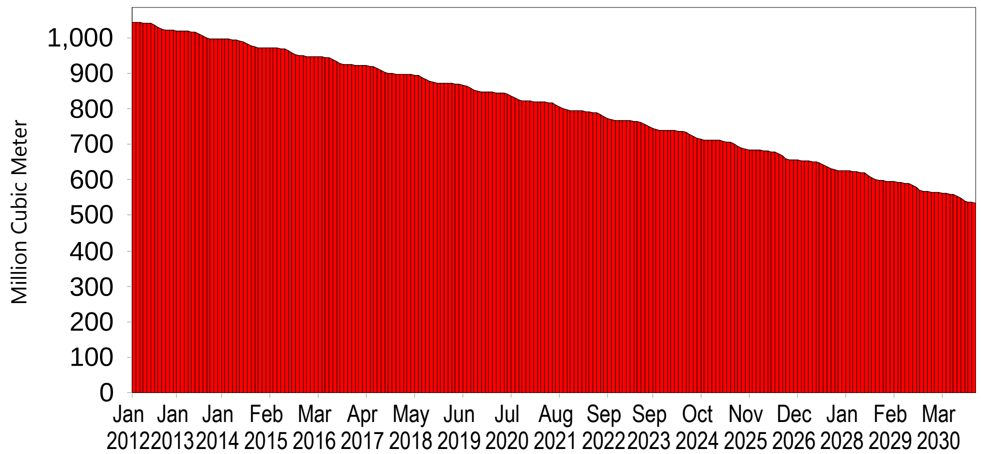


Figure 5.2: Ground water storage up to 2030 under Sc.1.

5.1.2 Results of Scenario 2

For the safe use of treated waste water, the World Health Organization (WHO) and the Palestinian specification recommends its use only in the trees, and by the expected water quality through the treatment plant to be built can use that water to irrigate citrus trees and olive trees and palm trees as well as ornamental trees and alfalfa. According to statistics, the required quantities to irrigate trees are shown Table 5.2

Table 5.2 :Results of scenario No.2 using treated wastewater in agricultural irrigation

Orchards trees	Existing Total area (dunum)	Gross Irrigation (m3/du)	Total Irrigation demand (MCM/area)	Irrigated area (dunum) 2018	Irrigation using TWW 2018 (9.5MCM)	Irrigated area (dunum) 2025	Irrigation using TWW 2025 (16.4)MCM
Olive	12,000	515.7	6.19	12,000	6.19	12,000	6.19
Palm	2,390	1091.5	2.61	1,364	1.49	2,390	2.61
Fruits	4,956	591.4	2.93	0	0	4,956	2.93
Citrus	2,505	730.2	1.82	2,505	1.82	2,505	1.82
Vegetables	14,537	530.8	7.71	0.0	0.0	5,382	2.85
Rain-fed crops	25,530	100	2.55	0.0	0.0	0.0	0.0
Total	61,918		24.24	15869	9.5	27233	16.4

From Table 4.6, the total area that can be irrigated by treated wastewater year 2018 is equal 15,869 dunum and it can irrigates completely olives, citrus and partially the palm orchards. It means that it can be covered by 71% of the consumption of olive trees, citrus trees and palm trees. By the year 2025 the second phase of construction WWTP will be finished and generated quantities can be extracted through recovery wells surrounding the infiltration basin area is 16.4 MCM annually which exceeds the amount of trees consumption by 2.85 MCM per year starting from the year 2025.

- **Ground Water Storage**

To find out how the use of treated waste water will influence the aquifer WEAP software were used. As is shown Figure 5.3 the generated quantities that will be pumped from the treatment plant to the infiltration basins on a monthly basis starting from 2018, according to the operational plan for the treatment plant at a rate of 0.79 MCM until the year 2025 and then to 1.34 MCM per month starting from the year 2025.

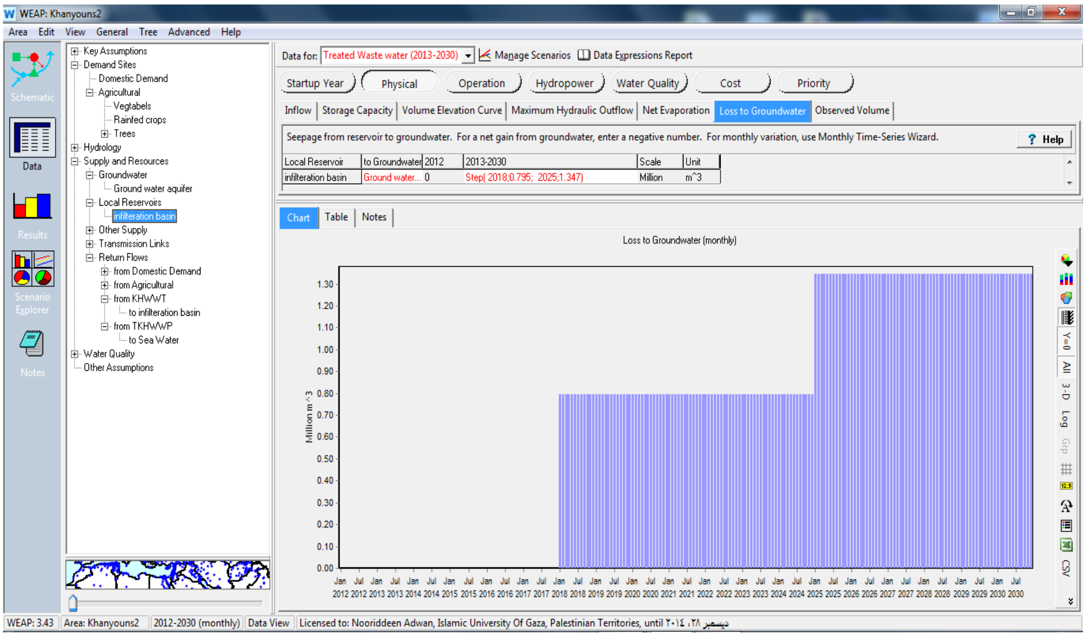


Figure 5.3 WEAP screen input of infiltration basin at 2018 – 2025

In reviewing the results of this scenario, the use of treated waste water that is withdrawn from wells surrounding area of infiltration basins are illustrated in Figure 5.4 it's found compared baseline scenario (business as usual) with the scenario of using treated wastewater , it is clear that the second scenario is the better for the storage of aquifer where the storage in the years from 2013 until 2018 decreases significantly.

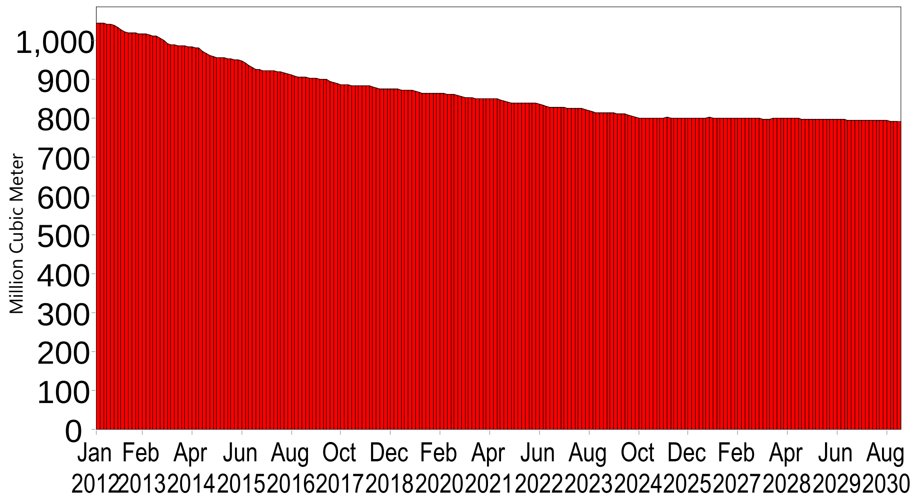


Figure 5.4 Influence of ground water storage after treated waste water (Sc.2) using WEAP

In year 2018 with the startup of the plant and withdrawals through recovery wells surrounding the infiltration basins. The attrition rate at least to a large extent , and with the beginning of the year 2025 with the start of operation of the second phase of the treatment plan, it was found that the storage of the aquifer begins to grow at a rate of a few, and this is explained by that according to the outputs of the station. They cover the value of 9.0 MCM annually which minimize pressure on the aquifer and falling rate becomes small. Also with the operation of the second stage the production amounted raise to 16.4 MCM annually , therefore , as it is seen in Figure 5.5 storage aquifer will increase which affects positively the water level of the aquifer.

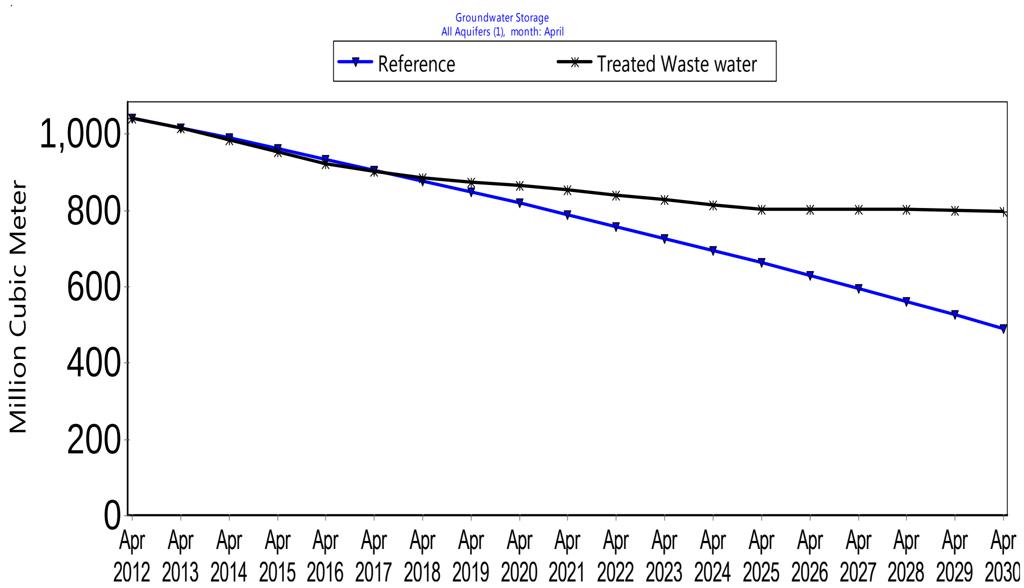


Figure 5.5 Comprasion between scenario No.1 & scenario No.2 for ground water storage

- **Quality of treated wastewater for agricultural irrigations :**

According to scenario No.2 results, the quality of treated waste water should be monitored and the required quality for irrigation water for orchards and crops eaten row should be insured according to the specification in Table 5.3.

Table 5.3 Recommended guidelines for agricultural reuse of wastewater

Types of Reuse	Treatment	Reclaimed Water Quality	Reclaimed Water Monitoring
Agricultural Reuse – *Food Crops Not Commercially Processed* Surface irrigation of Orchards and Vineyards	Secondary Disinfection	= 30 mg/l SS = 200 fecal coli/100ml4,5 1 mg/l Cl2 residual (min.)	BOD - weekly SS - daily Coliform - daily Cl2 residual - continuous
Agricultural Reuse – *Food Crops Not Commercially Processed* Surface or spray irrigation of any food crop, including crops eaten raw	Secondary Filtration Disinfection	= 10 mg/l BOD No detectable fecal coli/100ml3 1 mg/l Cl2 residual (min.)	BOD - weekly Coliform - daily Cl2 residual - continuous

5.1.3 Results of Scenario 3

- **Domestic and Agricultural demand**

❖ ***Option I***

The results for the option I as shown Table 5.4 indicate that the total irrigation demand is 22.89 MCM annually , which less than the existing situation by 1.35 MCM.

Table 5.4 Option I for changing crop pattern under Sc.3

Orchards trees	Existing Total area (dunum)	Gross Irrigation (m^3/du)	Total Irrigation demand (MCM/area)	Option I	Gross Irrigation (m^3/du)	Total Irrigation demand (MCM/area)
Olive	12000	515.7	6.19	15700	515.7	8.09
Palm	2390	1091.5	2.61	1500	1091.5	1.63
Fruits	4956	591.4	2.93	3451	591.4	2.04
Citrus	2505	730.2	2.25	1200	730.2	0.87
Vegetables	14537	530.8	7.71	14537	530.8	7.71
Rain-fed crops	25530	100	2.55	25530	100	2.55
Total	61918		24.24	61918		22.89

❖ *Option II*

The results for option II as shown in Table 5.5 indicate that the total irrigation demand is 18.18 MCM annual , which less than the existing situation by 6.06 MCM.

Table 5.5 Option II for scenario changing crop pattern

Orchards trees	Existing Total area (dunum)	Gross Irrigation (m^3/du)	Total Irrigation demand (MCM/area)	Option II	Gross Irrigation (m^3/du)	Total Irrigation demand (MCM/area)
Olive	12000	515.7	6.19	12000	515.7	6.19
Palm	2390	1091.5	2.61	0	1091.5	0
Fruits	4956	591.4	2.93	0	591.4	0
Citrus	2505	730.2	2.25	1200	730.2	0.87
Vegetables	14537	530.8	7.71	14537	530.8	7.71
Rain-fed crops	25530	100	2.55	34181	100	3.41
Total	61918		24.24	61918		18.18

❖ *Option III*

The results for the option III as shown in Table 5.6 indicate that the total irrigation demand is 15.48 MCM annual , which decrease than the existing situation by 8.76 MCM.

Table 5.6 Option III for scenario changing crop pattern

Orchards trees	Existing Total area (dunum)	Gross Irrigation (m^3/du)	Total Irrigation demand (MCM/area)	Option III	Gross Irrigation (m^3/du)	Total Irrigation demand (MCM/area)
Olive	12000	515.7	6.19	12000	515.7	6.19
Palm	2390	1091.5	2.61	0	1091.5	0
Fruits	4956	591.4	2.93	0	591.4	0
Citrus	2505	730.2	2.25	0	730.2	0
Vegetables	14537	530.8	7.71	10000	530.8	5.30
Rain-fed crops	25530	100	2.55	39918	100	3.99
Total	61918		24.24	61918		15.48

By the comparing between the existing situation and three options for the total irrigation demand, as shown in Table 5.7 it was found that the third option has the lowest irrigation demand water annually with the same area of the cultivation area, due to it depends on the rain-fed crops, that means this option save 8.76 MCM annually.

Table 5.7 Total irrigation demand for three option

	Total Irrigation demand (MCM/area)			
Crops	**Existing Situation**	**Option I**	**Option II**	**Option III**
Olive	6.19	8.09	6.19	6.19
Palm	2.61	1.63	0	0
Fruits	2.93	2.04	0	0
Citrus	2.25	0.87	0.87	0
Vegetables	7.71	7.71	7.71	5.30
Rain-fed crops	2.55	2.55	3.41	3.99
Total MCM	24.24	22.89	18.18	15.48
Saving regarding reference scenario MCM annually	**0.0**	**1.35**	**6.06**	**8.76**

Figure 5.6 shows that the demand for Khanyounis governorate is increasing over time due to an increase in population while the agriculture demand varies according to the three option assumption with different area of crop pattern. For option I the demand quantities is 22.89 MCM annually, 18.18 MCM for option II, and 15.48 MCM for option III

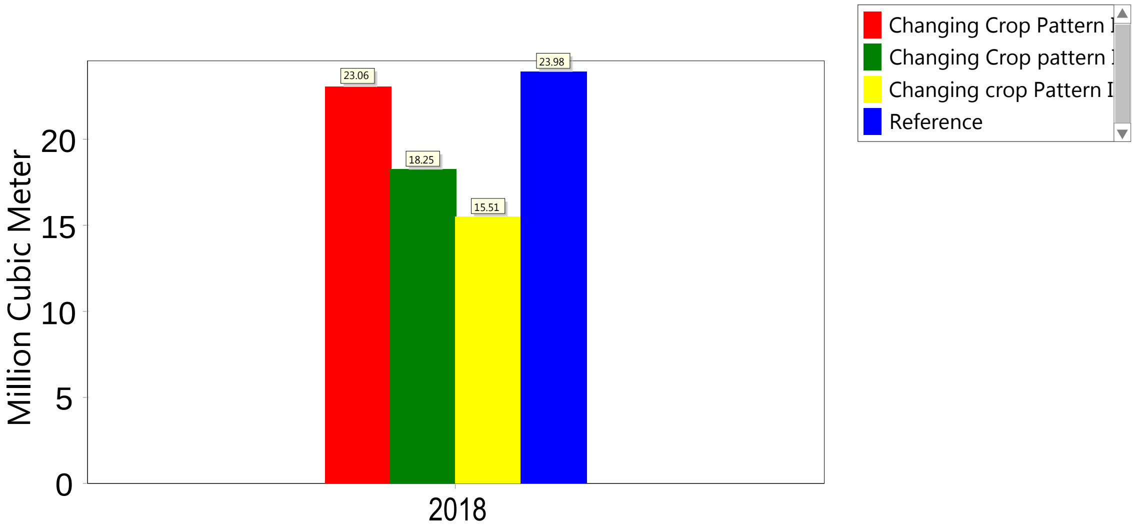


Figure 5.6: Domestic and agricultural demand for Khanyonuis governorate up to 2030 under Sc.2.

- **Ground Water Storage**

In reviewing the results of this scenario, three different option of Changing crop pattern. Figure 5.7 illustrated compared baseline scenario (business as usual) with the scenario of changing crop pattern , it is clear that the second scenario is the better for the storage of aquifer where the storage in the years from 2013 until 2018 decreases significantly.

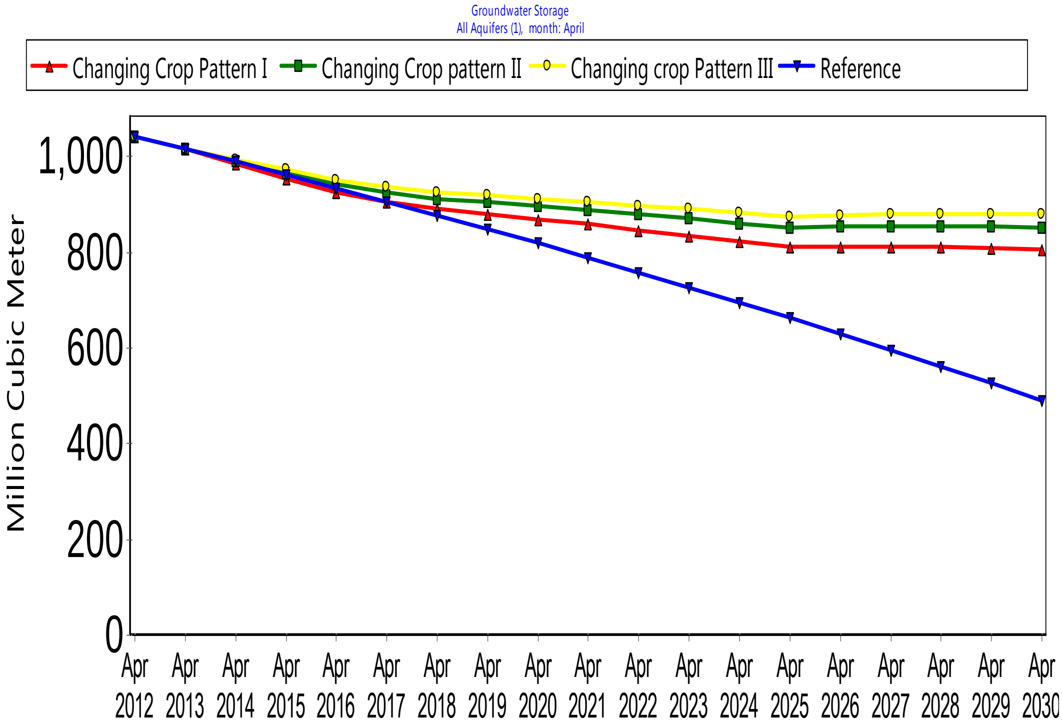


Figure 5.7 WEAP results for comparison between 3 option of scenario changing crop pattern

5.1.4 Results of Scenario 4

- **Water Balance**

In this scenario the results represent the usage of treated waste water from recovery wells surrounding the infiltration basins with changing the crop pattern as in scenario no.2. Table 5.8 below shows how treated waste water can be used with different options of crop pattern, and to find the optimal scenario can be applied.

Table 5.8 Combination of scenario No.2 & Scenario No.3 results

Crops	Existing Situation	Option I	Option II	Option III
Olive	6.19	8.09	6.19	6.19
Palm	2.61	1.63	0	0
Fruits	2.93	2.04	0	0
Citrus	2.25	0.87	0.87	0
Vegetables	7.71	7.71	7.71	5.30
Rain-fed crops	2.55	2.55	3.41	3.99
Total MCM	24.24	22.89	18.18	15.48
Total TTW 2018	26000 m^3/day = 9.50 MCM / year			
Total TTW 2018	44900 m3/day = 16.40 MCM/year			
Saving (MCM) 2018	9.5+0 (9.50)	9.5+1.35 (10.85)	9.5+6.06 (15.56)	9.5+8.76 (18.26)
Saving (MCM) 2025	16.4+0 (16.40)	16.40+1.35 (17.75)	16.40+6.06 (22.46)	16.40+8.76 (25.16)

As shown in Table 5.8, the combination between the two scenarios by considering three different options for crop patterns, can save fresh water from groundwater aquifer equal to 16.40 MCM annually without any change in crop pattern. while in the first option 10.85 MCM and 17.75MCM of fresh water can be saved in the years 2018,2025 respectively. But in the second option the saved quantities reach up to 15.56 MCM and 22.46 MCM in the years 2018 ,2025 respectively. In the third option the saved fresh water quantities reach to 18.26 MCM and 25.16 MCM annually in the years 2018 , 2025 respectively .

5.2 *Comparison of Scenarios*

5.2.1 Ground Water Storage

In reviewing the results form WEAP module, comparison between four scenarios as shown in Figure 5.8, it is clear that the third scenario is the best for the storage of aquifer where the storage in the years from 2013 until 2018 decreases significantly.

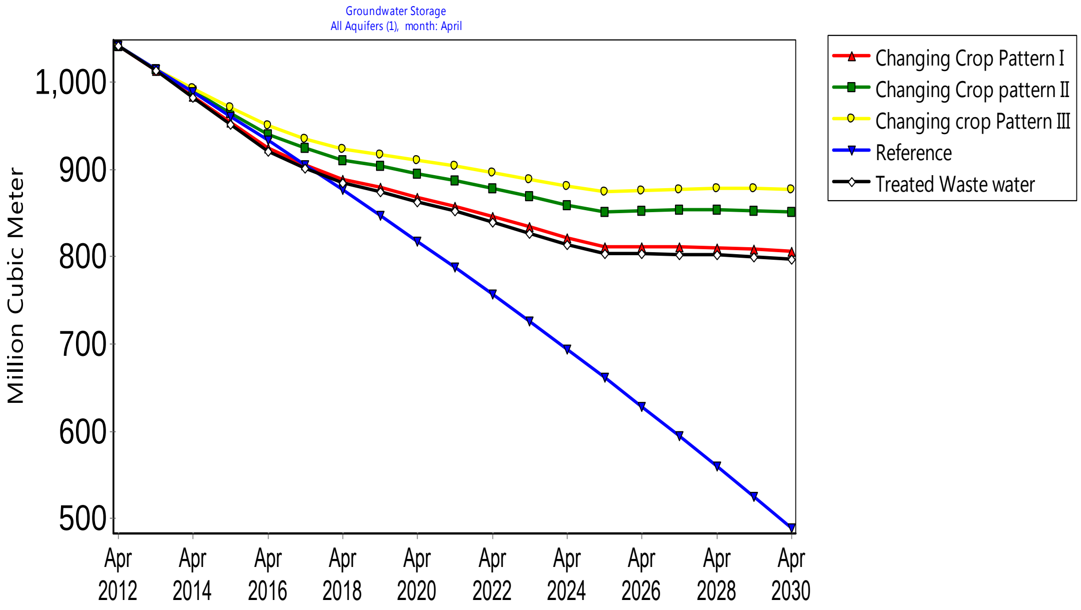


Figure 5.8 WEAP results for comparison between 4 Scenarios

5.2.2 Water Balance

By exploring the water balance at year 2030 for the four scenarios as shown in table 5.9, The reference scenario shows that the deficit will be 28.30 MCM annually while in the second scenario (using TWW in agricultural irrigation) it will be reduce to 11.90 MCM with recovery quantities form infiltration basins 16.40 MCM annually. The third scenario shows that the deficit quantities will be reduce to 26.99, 22.28 and 19.50 MCM respectively for the three options. In the fourth scenario the deficit will be more reduced than other three scenarios with deficit of 10.59, 5.88, and 3.18 MCM annually respectively for the three options .

Table 5.9 Water balance for the four scenario till the year 2030

Water Balance		**(2030) Reference scenario**	**(2030) Using TWW scenario**	**(2030) Changing crop pattern scenario**			**(2030) Comb 2&3 scenario**		
				Option I	Option II	Option III	Option I	Option II	Option III
Inflow (MCM)	Infilterated Rainfall	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
	Return Flow	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
	Lateral Inflow	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Net Ground Inflow (MCM) =		17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6
Out Flow (MCM)	Municipal	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7
	Agricultural	24.2	24.2	22.89	18.18	15.48	22.89	18.18	15.48
Net Ground Water outflow (MCM) =		45.9	45.9	44.59	39.88	37.18	44.59	39.88	37.18
Reuse of TWW in agricultural =		0	16.40	0	0	0	16.40	16.40	16.40
Net Balance – deficit (MCM) =		**-28.3**	**-11.90**	**-26.99**	**-22.28**	**-19.50**	**-10.59**	**-5.88**	**-3.18**

CHAPTER

6

Conclusions & Recommendations

6.1 Conclusions

Khanyounis governorate (study area) is considered as one of the largest consumer of the water in agricultural sector in Gaza strip. The total cultivated area are 61,918 dunum according to the last update of MOA and the survey of research . Based on the outcome of this work, the following concluded remarks could be stated :

- The net agricultural land that cultivated are 61,918 dunum distribute over all governorate which divided into main three categories : vegetables crops with an area equal 14,560 dunum , Orchards tress of an area about 21,500 dunum , and Rain-fed crops with an area equal of 25,500 dunum.
- The total consumption of water in 2013 for domestic demand is about 11 MCM , and it's expect to increase gradually to reach to 24 MCM in 2030 according to normal population growth (3.5% annual).
- The total consumption of water in agricultural sector is 25MCM in 2013 according to MOA , the estimated CWR according to cropwat module is close.
- Four scenarios are developed to find a plan to manage the water problem, as follow, business as usual, using treated waste water, changing crop pattern and combination between scenario 2&3.
- The deficit in the water balance will increase over the time to reach 28.30 MCM in year 2030. Due to continuous abstraction from the ground water aquifer WEAP can explore the storage of ground aquifer among the period of scenario until 2030.

A decrease in the quantity of fresh water will occur. This decrease will be substituted by sea water which increasing the sea water intrusion .

- The results of first scenario, shows that an increase of consumption of water reach to 45.91 MCM at 2030 comparing with 2013 water consumption with differences more than 10MCM annually.
- The results of second scenario, show that use of treated waste water will save annual 9.0 MCM from 2018 to 2025 and 16.40 MCM after 2025. These abstracted quantities can be used in tress irrigations according to Palestinian standards. This will minimize pressure on the aquifer and water level and falling rate will become small.
- The results of third scenario, comparison between the existing situation and three options for the total irrigation demand it was found that the third option has the lowest annually irrigation demand with the same area of the cultivation area. Since it depends on the rain-fed crops. This option save 8.76 MCM annually .
- The results of fourth scenario, concluded that it can save fresh water from groundwater aquifer equal to 16.40 MCM annually without any change in crop pattern. while in the first option 10.85 MCM and 17.75MCM of fresh water can be saved in the years 2018,2025 respectively. But in the second option the saved quantities reach up to 15.56 MCM and 22.46 MCM in the years 2018 ,2025 respectively. In the third option the saved fresh water quantities reach to 18.26 MCM and 25.16 MCM annually in the years 2018 , 2025 respectively.

6.2 Recommendations

Based on the concepts developed and results concluded throughout this work, the following recommendations might be considered for future:

- Palestinian decision makers either at the Ministry of Agriculture, Palestinian Water Authority, or the Ministry of Planning have to consider that the quantities of treated wastewater to minimize the shortage in water sources in the area. The quality of raw wastewater is considered acceptable for reuse after treatment according to the design criteria of the WWTP.
- The agriculture sector, which is the highest water consumer in Gaza Strip, should be managed through the more efficient use of water, through adopting new crop patterns and utilization of alternative water resources (treated wastewater). And generalize modern irrigation and conservation techniques in the irrigated agriculture.
- Licensing, metering of wells specially agricultural wells and introduction of an appropriate tariff are matter of urgency to improve water conservation and controlling the abstraction.
- This research should be expanded to cover all Gaza Governorates .
- The WEAP should be a compared with ground water model and cost analysis models to investigate in more optimal options with concerned to water irrigation and crop patterns.

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