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Groundwater in Egypt's Deserts

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Preface

No doubt that groundwater is an essential source of water resources in many regions in the world particularly in arid desert areas as in the case of Egypt. Egypt's deserts rely on groundwater where no other reliable source is available. The rapid growth of the population and the need for food at a reasonable price lead Egypt to extend its agricultural expansion to the deserts where 1.5 million feddans (1 Feddan = 4200 m^2) are entering the plan for cultivation. This book focuses on the groundwater in Egypt's deserts, its availability, quantity, quality, uses, and the future agricultural expansion. The book consists of 17 chapters in five parts.

Part "Introductory Section" is an introduction and contains two Chaps. "Introduction to "Groundwater in Egypt's Deserts"" and "An Overview of the Egyptian Deserts' Resources" as an introductory section to the book. Chapter "Introduction to "Groundwater in Egypt's Deserts"" introduces the book to the audience, where it presents a very brief description of the technical elements of the chapters. While in Chap. "An Overview of the Egyptian Deserts' Resources", an overview of the resources in Egypt's desert including the general features of the Egyptian deserts, the main geographical units, the main characteristics of the natural resources in Egyptian deserts.

Part "Groundwater Occurrence and Ecosystem Services" includes Chaps. "Groundwater Ocurrences in West Nile Delta, Egypt" and "Characterizing Ecosystem Services to Human Well-Being in Groundwater Dependent Desert Environments" that are devoted to groundwater occurrence and ecosystems associated with groundwater availability in the deserts. Chapter "Groundwater Ocurrences in West Nile Delta, Egypt" classifies and assesses the geological, geophysical, hydrological, and hydrochemical bases of the existed aquifers in the study area which are represented by the Oligocene and the Miocene aquifers. The chapter also aims to create baseline data to be used as a guide to monitor and detect the future changes in the groundwater level and quality clarifying the roles of lowering the groundwater levels, aquifer depletion, increase in water salinity and mixing between different aquifers. While Chap. "Characterizing Ecosystem Services to Human Well-Being in Groundwater Dependent Desert Environments" explores the merits of the ecosystem services framework as a means to characterize the services associated with groundwater availability and use in Egypt and to begin to capture their value with a focus on the Western Desert to illustrate the scope to apply the ecosystem service characterization and assessment approach and also highlights areas where Egyptian groundwater managers could invest in improving information systems for this purpose.

Part "Groundwater Exploration, Quantity, Quality, and Their Management" deals with Groundwater Exploration, Quantity, Quality and their Management in 8 Chapters from "Geophysical Groundwater Exploration in Arid Regions Using Integrated Land-Based Magnetic and DC Resistivity Measurements: A Case Study at Gilf Kebir Area, South Western Desert, Egypt" to "Assessment of Groundwater Resources in Egypt's Deserts". Chapter "Geophysical Groundwater Exploration in Arid Regions Using Integrated Land-Based Magnetic and DC Resistivity Measurements: A Case Study at Gilf Kebir Area, South Western Desert, Egypt" is titled (Geophysical groundwater exploration in arid regions using integrated DC resistivity and Magnetic modeling: A case study at Gilf Kebir area, Southwestern Desert, Egypt). It focuses mainly on evaluating the groundwater accumulations of the areas through the determination of the aquifer geometry as well as the depth to the water level that is done by applying surface geophysics techniques with remote sensing information. Additionally, Chap. "Ground Water Potentiality in Siwa and Baris Oases, Western Desert, Egypt" is about (Ground Water potentiality in Siwa and Baris Oases, Western Desert, Egypt). It deals with the employment of geological and geoelectrical and hydrogeological techniques for evaluation of the potentiality of groundwater in Siwa and Baris Oases that are located in the Western Desert. Chapter "Groundwater and Characteristics of the Tertiary-Quaternary Aquifer System West of Mallawi, Upper Egypt" is titled (Groundwater and Characteristics of the Tertiary-Quaternary Aquifer System West of Mallawi, Upper Egypt) and evaluates the characteristics of the existed aquifers and assessment of the groundwater potentialities and quality at the west of Mallawi area aiming to realize the sustainable development of such area.

On the other hand, Chap. "Groundwater Characterization and Quality Assessment in Nubian Sandstone Aquifer, Kharga Oasis, Egypt" which is titled (Groundwater Characterization and Quality Assessment in Nubian Sandstone Aquifer, Kharga Oasis, Egypt) assesses the hydro-geochemical characteristics in the Nubian Sandstone Aquifer (NSSA) in Kharga Oasis by identifying major variables affecting the quality of groundwater and evaluating the suitability of groundwater for domestic and agricultural purposes. GIS is used to create thematic maps for the most important parameters associated with groundwater quality. Moreover, Chap. "Groundwater Potential in the Bahariya Oasis, Western Desert, Egypt" under the title (Groundwater Potential in the Bahariya Oasis, Western Desert, Egypt) evaluates the hydrogeological conditions of the groundwater in Bahariya Oasis to determine its potentialities for optimum exploitation of groundwater, using the available data and field measurements and investigating the water exploitation effect on water quality of the aquifer. Additionally, Chap. "Groundwater Quality and Potentiality of Moghra Aquifer, Northwestern Desert, Egypt" with the title (Groundwater Quality and Potentiality of Moghra Aquifer, Northwestern Desert, Egypt) deals with the water quality and potentiality of the groundwater of the Lower Miocene aquifer in the Moghra area to delineate the subsurface geologic setting and the affecting structural elements (faulting and fractured zones). It shows the occurrence of groundwater resources in the Lower Miocene aquifer and investigates the hydrogeological characteristics of the lower Miocene aquifer by using geochemical and geophysical methods.

On the other hand, the topic (Transboundary groundwater management issues in the Nubian Sandstone Aquifer System (NSAS) is covered in Chap. "Transboundary Groundwater Management Issues in the Nubian Sandstone Aquifer System (NSAS)" which explores how Egypt can lead the way forward toward the sustainable utilization of the NSAS by sharing insights with the other riparian countries concerning available management technologies and innovations as it pushes the boundaries of science, engineering, and ecosystem management to respond to pressing shared water management challenges. Conserving the quality of groundwater and keeping it away from pollution by sewage system is discussed in Chap. "Groundwater Quality for Irrigation as an Aspect of Sustainable Development Approaches: A Case Study of Semi-Arid Area Around Ismailia Canal, Eastern Nile Delta, Egypt" which is titled (Groundwater quality for irrigation as an aspect of sustainable development approaches: a case study of semi-arid area around Ismailia Canal, Eastern Nile Delta, Egypt) with a focus on an area in the East of the Nile Delta where the land is semi-arid or arid. While Chap. "Assessment of Groundwater Resources in Egypt's Deserts" closes this section by making an assessment of the groundwater resources in Egypt's deserts and discusses its availability and sustainability.

In "Potential Use of Groundwater and Future Expansion", 3 chapters are presents to cover the theme (Potential Use of Groundwater and Future Expansion). This theme is devoted to the Potential Use of Groundwater and Future Expansion of agricultural projects and their needs for water. It is covered in three chapters. Chapter "Groundwater Exploitation in Mega Projects: Egypt's 1.5 Million Feddan Project" provides a brief description of the Mega agricultural project in Egypt. An overview of the general vision and strategy adopted by the MWRI highlights the MWRI's plans. On the other hand, Chap. "Optimum Economic Uses of Precious Costly Ground Water in Marginal and Desert Lands; Case Study in Egypt" explains the various possible ways to optimize the use of the scarce groundwater source which might be non-renewable. The last chapter in Part "Potential Use of Groundwater and Future Expansion" is dealing with the overall assessment of the water resources in Egypt including the share of the groundwater. The chapter presents the expected water resources demand in Egypt in the year 2025 and in the year 2050 to draw the attention of the concerning authorities to take care of this very critical file to the life of the Egyptians.

The last Part of the book is to conclude the book with a chapter titled (Update, Conclusions and Recommendations of the Groundwater in Egypt's Deserts". It closes the volume of the book with the main conclusions and recommendations for the benefits of the readers, policy planners, decision-makers, and stakeholders.

Last but not least, we want to thank all who contributed to this high-quality volume, which is a real source of knowledge and the latest research findings in the field of groundwater in Egypt's Deserts. We would love to thank all the authors for their invaluable contributions. Much appreciation and great thanks are also owed to the editors of the Earth and Environmental Sciences series at Springer for constructive comments, advice, and critical reviews particularly Andrey Kostianoy and Alexis Vizcaino. Acknowledgments are extended to include all members of the Springer team who have worked long and hard to produce this volume.

Additional Abdelazim Negm and Ahmed Elkhouly acknowledge the support of the Science, Technology, and Innovation Authority (STIFA) of Egypt in the framework of grant no. 30771 for the project titled "a novel standalone solar-driven agriculture greenhouse—desalination system: that grows its energy and irrigation water" via the Newton-Mosharafa funding scheme.

Comments and feedback from the current and audiences are most welcomed to improve the quality of the books in the next editions. New chapters are welcomed for the next edition from any potential qualified author.

Zagazig, Egypt, December 2019 Abdelazim Negm
Cairo, Egypt, September 2019 Ahmed Elkhouly

Contents

Introductory Section

Introduction to “Groundwater in Egypt’s Deserts”

Abdelazim M. Negm, El-Sayed E. Omran, and Ahmed Elkhouly

Abstract In this chapter, a brief description of all the chapters of the book is presented. Therefore, the chapter contains the basic idea behind each chapter. The chapters are organized under five themes that are Introductory section (2 chapters), groundwater occurrence and ecosystem services (2 chapters), groundwater resources, quantity, quality and their management (8 chapters), and potential use of groundwater and future expansion (3 chapters) and the conclusion section (1 chapter). In addition to this, chapter “Overview of the Egyptian Desert’s Resources” introduces briefly the natural resources in Egypt’s deserts. Almost the information presented in this chapter does not have much about the results and the conclusion. The results and its analysis are provided in the body of the chapters. Each chapter ends with a set of conclusions and recommendations as well. A separate chapter to close the book is devoted to the update of the literature and to present the most important conclusions and recommendations from the book chapters.

Keywords Water logging · Assessment · Sustainability · Groundwater · Deserts · Environment · Egypt · Oasis · Agriculture

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Background

The Egyptian deserts are located in the hyper-arid regions of North Africa. The water resources in the desert are mainly groundwater. Most of the soil texture in the Egyptian desert is sand. The natural resources in the Egyptian deserts subjected to degradation and deterioration mainly by land salinization, water deficiency and wind erosion.

The Egyptian deserts comprise three main geographical units: the Western desert; the eastern desert; and the Sinai Peninsula. Most of the Egyptian desert is located in the hyper-arid regions with annual rainfall in most parts of less than 50 mm. Hyperarid provinces include all the area between Lat 22° and 30° N, except the coastal mountains along the Gulf of Suez (a representative figure is presented in chapter 2). The arid provinces include the northern section with winter rainfall, it extends along the Mediterranean coast and the Gulf of Suez. The main habitats in the Egyptian deserts are distinguished to wadies, sand formations, gravel formations, salt marshes and reed swamps. The desert's water resources are primarily groundwater. Egypt has two main groundwater aquifers the first comprises groundwater in the Nile Valley and Delta system and the second aquifer is the non-renewable type, which is located in the Western Desert of the Nubian Sandstone, where the groundwater exists and deep-seated. The main soil types occurring in the Egyptian deserts are: Calcic Yermosols, Haplic Yermosols, Orthic Solonchaks, Eutric Regosols, Calcaric Regosols, Haplic Xerosols, Lithosols and Shifting sand. Flora of Egypt comprises about 2121 species of vascular plants including 27 species cultivated. Egypt is the meeting point of floristic elements belonging to at least three phytogeographical regions: the African Sudano- Zambesian; the Asiatic Irano- Turanian; the Afro- Asiatic Saharo- sindian and the Euro- Afro- Asiatic Mediterranean. The desert vegetation is formed mainly of xerophytic shrubs and sub-shrubs. Domestic animals in Egyptian Deserts include camels, donkeys, sheep, and goats. The largest wild animal is the Aoudad (a type of bearded sheep), which survives in the southern fastness of the Western Desert. Other desert animals are the Dorcas gazelle, the Fennec (a small, desert-dwelling fox), the Nubian ibex, the Egyptian Hare, and two kinds of Jerboa (a mouse-like rodent with long hind legs for jumping). Interested reading can go for more detail in chapter 2 titled "**Overview of the Egyptian Desert's Resources**".

It is worth mentioning that this book comes follower to the book edited by Negm [1] and the one edited by Negm and El-Rawy [2] with the titles "**Groundwater in the Nile Delta**" and "**Groundwater in the Nile Valley Aquifer, Egypt**", respectively, to add additional insights to the picture of the groundwater availability, quality and quantities in Egypt particularly in Egypt's deserts.

Themes of the Book

Therefore, the book intends to address in more detail the following main themes:

– Groundwater Occurrence and Ecosystem Services.
– Groundwater Exploration, Quantity, Quality and Their Management.
– Potential Use of Groundwater and Future Expansion.

Chapter's Summary

The next subsections describe briefly the main technical elements of each chapter under its relevant theme.

Groundwater Occurrence and Ecosystem Services

This theme is covered in chapters 3 and 4. Chapter 3 is titled "**Groundwater Occurrences in Western Nile Delta, Egypt**". It presents an integration of the geoelectrical, hydrological, hydro-geochemistry and isotopic techniques that were applied to evaluate the groundwater potential in the West Nile Delta area. Since, the West Nile Delta suffered from the deterioration in groundwater due to the intensive exploitation which resulted in both groundwater depletion and salinity increase. For the potential management of groundwater supplies, monitoring and evaluating changes in groundwater level, performance, aquifer renewability and mixing between existing aquifers were therefore very necessary. The geoelectrical and hydrological results reveal that there are two aquifers separated by a basaltic sheet. The first one is represented by the Miocene aquifer (El-Moghra) and the second one is the Oligocene aquifer which has a lower resistivity than the upper one and this is mainly due to the increase of clay content and the water salinity. Also, these results reveal that the saturated thickness of Miocene aquifer decreased during the years (2003–2015) period which ranged between 1.3 and 1.7 m/year and the total dissolved solids (TDS) content of groundwater samples varied from 234 to 2458 mg/L implying significant deterioration and salinization problems. The δ18O-δ2H relationship was suggesting that two nonrenewable groups. Results indicate that most wells operate at relatively high pumping rates followed by low efficiency and different capacities in addition to decreasing well yields and deteriorating water.

Moreover, chapter 4 with the title "**Characterizing Ecosystem Services to Human Well-Being in Groundwater Dependent Desert Environments**" is focusing on the exploration of the ecosystem services associated with groundwater reserves and extraction. These can be characterized, compared, and weighed in qualitative and quantitative terms by decision-makers. It will assist groundwater managers in assessing groundwater management decisions pros. and cons. Management decisions are often based on information that is very limited. When feasibility studies or economic assessments of groundwater decision-making have previously been made in Egypt, they have tended to focus only on the value of groundwater for agricultural production. By introducing a broader framework, ecosystem-service-based assessments should lead to better decision-making. Applying the framework for the evaluation of ecosystem services requires understanding, information and human capacity to effectively collect and use it. These can be mobilized through an iterative approach. The approach is illustrated through a case study located in the Nubian-Moghra Miocenene-Nile aquifer complex at Wadi Natrun in the Western Desert of Egypt. This provides insight into the potential for more ambitious use by decision-makers and scientists of the ecosystem service assessment method in areas where rapid groundwater extraction is already happening or may be accelerating in the future.

Groundwater Resources, Quantity, Quality and Their Management

This theme is covered in chapters from 5 to 13. Chapter 5 deals with the surface and subsurface mapping of the Nubian Sandstone Aquifer System (NSAS) and the delineation of subsurface structures predominant in the basement rocks, and their relationship with this aquifer in the area. The study area is the area of Gilf Kebir and its surroundings. They are considered as a case study for groundwater exploration using the conceptual geophysical program for mapping the groundwater potentialities in these hot climate and scarcity of rain desert areas. This work An integrated land-magnetic and DC resistivity methods were conducted with the employment of the geological and remote sensing data to delineate the shallow subsurface geological sections in terms of groundwater investigation. The study area is bounded by latitudes 220 00 and 230 00′ N, and longitudes 260 00 and 280 00′ E, covering an area of about 15,000 km^2. Four small locations were investigated namely; Eight Bills, Nosb El-Amir, Jabal Kamel and NE Jabal Kamel. Twenty two sounding points and 250 magnetic stations were carried out to illustrate aquifer geometry and basement relief, as well as prevailing hydrogeological conditions. The results will be helpful to guide the water resources management and environmental conservation in the Western Desert and other similar arid regions.

Moreover, chapter 6 is titled "**Groundwater Potentiality in Siwa and Baris Oases, Western Desert, Egypt**". This chapter deals with the employment of geological, geoelectrical and hydrogeological techniques to evaluate the potentiality of groundwater in Siwa and Baris Oases. The areas (Siwa and Baris oases) comprise two parts of the Western Desert, Siwa Oasis lies at 330 km southwest of Sallum and 65 km east of the Libyan borders, It is lying below the zero contour level elevation is usually considered as Siwa depression, while Baris Oasis lies at 90 km south of El-Kharga area. Hydrogeologically, the groundwater system that underlies Siwa Oasis consists of two productive aquifers. These are the Lower Cretaceous Nubian sandstone and the Middle Miocene fractured carbonates, while in Baris area consists of one productive aquifer that is the Nubian Sandstone aquifer.

However, chapter 7 is titled "**Groundwater and Characteristics of the Tertiary-Quaternary Aquifer System West of Mallawi, Upper Egypt**". The chapter explains the characteristics of groundwater in the west of Mallawi, where the groundwater exists I in three aquifers (Quaternary, Oligocene-Pleistocene and Middle Eocene Limestone Aquifer). The general trend of groundwater movement is from east to west. The water salinity of the three aquifers is less than 1000 ppm.

The dominated aquifers in the study area fall into two broad categories: The unconsolidated aquifers (granular) represented by Quaternary and Oligocene-Pleistocene. The consolidated fractured aquifer (fractured rock) represented by Eocene fractured limestone which considered as karst aquifer. The Quaternary aquifer in the flood plain is considered as highly productive where the aquifer has transmissivity values ranging between 6592 and 12,700 m^2/day and specific capacity ranging between 11.8 and 46.0 m^3/h/m. The water salinity of this aquifer ranges between 203.5 and 549.4 ppm increasing from east to west. The main source of recharge of this aquifer is the Nile water as indicated by the ion relationships. The Oligocene-Pleistocene aquifer is classified as moderately productive having transmissivity values ranging between 1256 and 6800 m^2/day and hydraulic conductivity ranges between 13.22 and 59.9 m/day with saturated thickness ranges between 91.5 and 113.5 m. The water salinity of this aquifer ranges between 719 and 801 ppm. For the Eocene fractured limestone aquifer, the aquifer is considered as highly productive aquifer having transmissivity values range between 1083 and 14,054 m^2/day. Its water salinity ranges between 462 and 845 ppm. The general flow direction of the granular aquifers (Quaternary and Oligocene-Pleistocene) is from east to the west as the Eocene fractured aquifer with some local change where there is a flow direction from southwest to the northeast direction which may be attributed to the over-exploitation in this locality or the effect of the fractures' orientation in this aquifer system.

Moreover, chapter 8 with the title "**Groundwater Characterization and Quality Assessment in Nubian Sandstone Aquifer, Kharga Oasis, Egypt**" provides baseline information on the groundwater quality and its suitability for different purposes of the Nubian sandstone aquifer in Kharga Oasis, Egypt. Hence, it could be useful for the management and sustainable development of the area. Also, it assesses the hydrogeochemical characteristics of groundwater in the Nubian Aquifer (NSSA) in Kharga Oasis and to evaluate its suitability for different purposes using field data and GIS techniques. Representative groundwater samples (144 samples) were collected and analyzed for various physiochemical attributes based on APHA [3]. The field surveys including wells location, well depth, ground elevation, and physicochemical properties were measured in situ. The results revealed that 93.8% of the samples are freshwater, whereas the rest 6.2% is slightly saline. Moreover, 35.4% of the samples are unsuitable for domestic purposes due to the high level of hardness. Salinity hazard, sodium percent, sodium adsorption ratio, residual sodium carbonate, magnesium hazard, Kelly's ratio, and soluble sodium percentage were used to evaluate groundwater quality for irrigation purposes, where most of the collected samples are unsuitable for agriculture under ordinary conditions.

Additionally, chapter 9 is titled "**Assessment of Groundwater Quality in Bahariya Oasis, Egypt**". It aims to evaluate the hydrogeological conditions of the groundwater aquifers (Nubian Sandstone Aquifer) in Bahariya Oasis. The hydrochemical analyses of 84 representative groundwater wells were carried out to determine the main hydrochemical characters, genesis and evaluation of the groundwater quality for different uses.

The physical and chemical characteristics were measured for the groundwater according to standard methods, such as temperature, turbidity, water electrical conductivity (EC), total suspended solids (TSS) and total dissolved solids (TDS), pH value, major anions and cations.

The average values of the EC, TDS, pH, major cations and anions did not violate the permissible limits of the drinking water set by the World Health Organization in 2011. Most of the three aquifer zones have freshwater averages of 286 mg/l. The average concentrations of heavy metals are higher than the permissible limit for manganese but lower for zinc.

Chapter 10 is titled "**Groundwater Quality and Potentiality of Moghra Aquifer, Northwestern Desert, Egypt**". It discusses the quality of groundwater in Moghra aquifer and its suitability for irrigation and drinking purposes. The Moghra area is a remnant of a larger paleolake including the mouth of a paleo-river. It is characterized by low relief and a mild topography with elevations -10 m below sea level to about 40 m above sea level. The geophysical study for 48 wells logs indicates great variations in lithology that consists of sand; sandstone and clay. The Moghra aquifer is under unconfined conditions. The formation of water resistivity of the aquifer generally increases towards the north. The decreasing of formation water resistivity in the south may be attributed to the decreasing in sand content and the existence of fine sand intercalated by shale and silt minerals. The formation factor increases towards the north. The effective porosity averages from 12 to 33%, and increases towards the west. The volume of shale is increased gradually towards the northwest. The origin of the Moghra aquifer is a mixture of water from different modern rainfalls, the water of post-Moghra aquifer, seawater and groundwater of Nubian Sandstone aquifer.

Chapter 11 is titled "**Transboundary Groundwater Management Issues in the Nubian Sandstone Aquifer System**". This chapter discusses Egypt's experiences in leading knowledge generation and sharing with other riparian countries to further the sustainable utilization of the major transboundary aquifer in Africa: the Nubian Sandstone Aquifer System (NSAS). It illustrates how the available management technologies and developments emerging in Egypt are pushing research, engineering, and ecosystem management boundaries to tackle the pressing challenges of shared water management.

The chapter first provides an overview of the growing sustainability challenges and innovations occurring in the NSAS. It then discusses the principles of sustainable utilization of groundwater in transboundary systems and provides a brief overview of the evolution of transboundary cooperation in the NSAS. The chapter observes that transboundary groundwater management initiatives have so far been state-led, and have focused on the generation of studies with the intent to share data between countries on the hydrological conditions of the aquifer.

A discussion of the challenges and way forward highlights the opportunity for increased engagement of local institutions to implement land and water management practices that conserve the health of the land that stores the groundwater reserves and enables their replenishment, to conduct or facilitate monitoring of groundwater conditions and to sustain the aquifer system. The extent to which this approach to groundwater management that is emerging in Egypt is innovative is underlined as one of the major conclusions.

Moreover, chapter 12 which is titled "**Groundwater Quality for Irrigation as an Aspect of Sustainable Development Approaches: A Case Study of Semi-arid Area Around Ismailia Canal, Eastern Nile Delta, Egypt**" discusses the need of conserving the quality of groundwater in the East of the Nile Delta where most of the land is semi-arid or arid. It is conducted to assessing the quality of the groundwater in the Quaternary aquifer of the semi-arid area Eastern Nile Delta region around Ismailia Canal, Egypt. The Suitability of groundwater for irrigation purposes is assessed too. This a basic evaluation investigation for understanding what management changes and practices that should be considered for conserving the soil from degradation, maintaining the soil productivity, restoring the maximum production capability and maintaining the full crop and long-term productivity under the given set of conditions.

Next to the above chapter, chapter 13 is titled "**Assessment of Groundwater Resources in Egypt's Deserts**" to provide an overall assessment of groundwater resources in Egypt. The chapter presents a general view on the Nile basin aquifers then the major six aquifers in Egypt. Different studies showing the groundwater abstraction rates, characteristics of the aquifers in the western, eastern and Sinai Peninsula.

The chapter begins by introducing the different Nile basin aquifers and their characteristics namely: Victoria artesian aquifer, Congo artesian aquifer, Upper Nile artesian aquifer, volcanic rock aquifers, Nubian sandstone aquifer, the Nile valley, and Nile Delta aquifers. Then, a brief introduction on the six major aquifers in Egypt is followed namely: Nile aquifer, Nubian sandstone aquifer, Moghra, Fissured carbonate, Coastal and the Hardrock aquifers. A brief history on the development and the exploitation of the groundwater and the consequences that latter followed it. The most recent studies and investigations are then outlined to show the groundwater extraction rates, salinity levels, the transmissivity of the soil aquifers, piezometric heads, etc. in different parts of Egypt's deserts. Models that simulate the groundwater flows n some areas are presented and simulation results for the future withdrawal rates are discussed. The recent advances in satellite imagery together with the integration of advanced techniques like GIS tools, Remote sensing, Watershed Modeling System, Enhanced Thematic Mapper Plus, and other surveying techniques are outlined to give the potential areas of groundwater across the country.

Potential Use of Groundwater and Future Expansion

This last theme in the book is devoted to discussing the economical use of the groundwater in Egypt's deserts, the agricultural expansion in Egypt's deserts and the overall assessment of water resources in Egypt to complete the picture of water resources and their distribution. In the chapter titled "Groundwater Exploitation in Mega Projects: Egypt's 1.5 million Feddan Project" the authors provide a brief description of the 1.5 Million Feddans project, including an overview of the general vision and strategy adopted by the MWRI to guarantee its sustainability and success. It highlights the MWRI's plans to avoid the mistakes that have been observed in past development projects that are dependent on groundwater management and to establish an effective system for predicting and monitoring economic and environmental impacts. The chapter presents the main points of both the proponents and the opponents of the project. The chapter stated that the establishment of the environmental monitoring system should be a high priority both for the groundwater resource users and for the government. This should be integrated with participatory planning for long-term sustainability, environmental risk assessment and disaster preparedness. While the chapter with the title "**Optimum Economic Uses of Precious Costly Groundwater in Marginal and Desert lands in Egypt**" explains the optimum economic using the precious, costly and nonrenewable desert groundwater in different sectors. In countries suffering from water shortage, particularly in arid and warm regions, the priority strategy of using groundwater should be planned as a result. The return of the water system in the industrial sector varies from 10 to 30 folds compared to the agricultural sector.

In countries that are suffering from water shortage especially in the arid and warm regions, the strategy of priority of using groundwater should by planned. The return back of the unit of water in the industrial sector is ranged between 10 and 30 folds than the agriculture sector. The industry sector uses a little of water which does not exceed 10% of the total water resources in the developing countries, but share in the GDP of the country 10 times more than the agriculture sectors which consume 85% of the total water resources. The labor income in the industrial sectors is higher as 2–10 times that of the labor income in the agriculture sector. Under specific conditions in some developing countries that are obliged to use the newly discovered groundwater in agriculture to reduce the food insecurity and the lack of foreign currency; scientific and logical policy should be followed. The priority of using groundwater in agriculture should be to the low temperature and seasonal rainfall area. Thus the new greening desert and agriculture extension projects in Egypt should be in the North and the Mediterranean coast of North Egypt which have a low temperature than south Egypt by 14 centigrade. The south, warm and low humidity region should have a priority for industry investments to reduce poverty and maximize the return back of water unite.

This theme ends with the chapter titled "**Assessment of Water Resources in Egypt: Current Status and Future Plan**" to introduce the current water resources supply and demands and the share of groundwater in the water resources budget in Egypt.

In this chapter, water resources in Egypt, both the conventional (Nile water, Deep groundwater, rainfall and flash floods and the desalinated water) and the non-conventional (shallow groundwater, reuse of the agricultural drainage water and the use of treated wastewater), have been presented. Data from different studies in the last 20 years have been collected and analyzed showing that the total water resources amount to approximately 82.8 billion cubic meters in the budget of 2017.

This is in addition to presenting the various sectors that consume water in Egypt like the agricultural, domestic, industrial, and other sectors (evaporation losses, environmental balance, fisheries, navigation, etc.). It is found that there is a gap that amounts to about 21 billion cubic meters in covering the water demands which pose pressure on the Egyptian government to accelerate the pace of an overall integrated water management policy.

By the end of the chapter, an overview of the different scenarios of the water budgets of the year 2025 and 2050 is presented. These scenarios take into account the accelerating population growth rate, climate change, the effect of the construction of projects in the upper Nile, the efficiency of the irrigation system and many other factors on the expected water consumption.

The book ends with the conclusions and recommendations chapter numbered 17. In the conclusions chapter, an update of the literature is made to cover some of the interesting topics which are related to the themes of the book. Some of these sources include [4–11].

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An Overview of the Egyptian Deserts' Resources

Ahmed A. Elkhouly, Abdelazim M. Negm, and El-Sayed E. Omran

Abstract Egypt total area found under arid and hyperarid climatic conditions, of which only a small portion (3% of total area) is agriculturally productive. Deserts in Egypt represent about 96% of Egypt's area. The Egyptian deserts comprise three main geographical units: the Western desert; the eastern desert; and the Sinai Peninsula. Egyptian deserts are located in the hyper-arid regions of North Africa and in Asia astride the Sahara and Arabian Desert with annual rainfall in most parts of less than 50 mm. The main habitats in the Egyptian deserts are distinguished to wadies, sand formations, gravel formations, salt marshes and reed swamps. The water resources in the desert are mainly groundwater. Most of the soil texture in the Egyptian desert are sand. The Egyptian flora is a mixture of flora that characterizes three continents: Africa, Asia, Europe, and this related to the geographical location of Egypt between the three continents. The natural resources in the Egyptian deserts subjected to degradation and deterioration mainly by land salinization, water deficiency and wind erosion.

Keywords Deserts · Egypt · Degradation · Land salinization · Natural resources · Groundwater · Habitats · Water deficiency · Vegetation · Animals

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Introduction

Egypt can be considered an African/Mediterranean country, although Sinia is a part of Asia. It occupies an area of about one million Km^2. It lies, between Latitude 22° and 32°N and Long 25° and 35°E. It is bordered by the Mediterranean Sea on the North while on the South it is bordered by the Republic of Sudan, on the West by Libya, and on the East by Palestine, Gulf of Aqaba and the Red Sea [1]. Egypt's total area found under arid and hyperarid climatic conditions, of which only a small portion (3% of total area) is agriculturally productive. Deserts in Egypt represent about 96% of Egypt's area (Fig. 1).

Egypt is a part of the Sahara "North African Desert". Its area is divided geographically by the River Nile into two main parts: a western part (Western Desert) of about 681,000 km^2 and an eastern part comprising the Eastern "Arabian" Desert 223,000 km^2 and the Sinai Peninsula 61,000 km^2. Nile Valley including the Delta forms, a riparian Oasis 40,000 km^2 that's the densely inhabited farmlands of Egypt.

With developing concerns approximately climate change and conceivable affect on natural system interruption and advancement forms have had evident unfavorable fingerprints on keeping up a healthy environment in Egypt's Lakes [2] and depressions. Water shortage issue may be a part of the climate change, which could be a

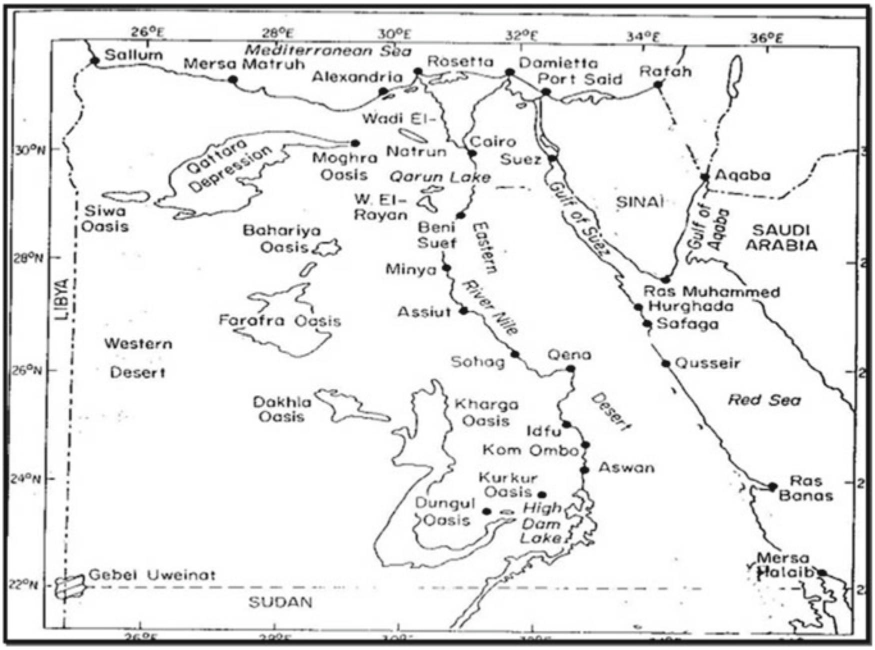

Fig. 1 Map of Egyptian deserts

developing issue around the world, with Egypt being hit especially difficult. Precipitation has relentlessly diminished, and temperatures have expanded. As temperatures take off and precipitation drops, crucial lakes are drying up [3].

Egypt is still attempting to reclaim the desert, to supply work and living space for its growing population and their growing settlements. Most fundamental nourishment items are imported, as generation is deficiently to meet population needs [4]. However, certain economists and environmentalists fear that the country's efforts to green the desert could be ill advised. This has prompted authorities in Egypt to develop plans—among other things—for large-scale resettlement. Egypt ought to utilize the desert to require care of the huge increment in population. population conditions in Egypt's desert are exceptionally distinctive from those within the valley and delta. Groundwater is the essential source of consumable water in a few nations, but there are challenges that influence supportability due to populace development, climate changeability, and land development [5]. The Nile River is the essential source of water in Egypt [6]. Egypt is confronting water shortage [7].

For sustainable socioeconomic developments in Egypt, resources management in desert is therefore important to protect limited resources. Egypt is divided into Agroecological zones. Each agroecological zone has critical varieties in environmental conditions. It is vital to focus on each area resources of these zones and monitoring of the resources and needs for development and capacity building and the development of appropriate legislation and recognize the beneficiaries of these areas of development [8].

The General Features of Egyptian Deserts

The Main Geographical Units

The Egyptian deserts comprise three main geographical units (Fig. 1):

i. The Western Desert;
ii. The Eastern Desert;
iii. The Sinai Peninsula

I. **Western Desert**

The Western Desert is occupying about 681,000 km^2. It extends over a vast area and composed of a large rocky surface with the highest portion in the southwestern corner where Gebel (mountain) Uweinat is found. North of Uweinat, the Gilf Eelkebir plateau (100 m amsl) occurred which forms from Nubian Sandstone [1]. This plateau is distinguished by slops decline sharply towards East and North to large depressions (Kharga and Dakhla depressions). To the North of this plateau, another plateau with arms extend in several directions. This plateau is composed of limestone and is lower in elevation than the Gilf Eel-kebir plateau, and constitutes the main landform feature West of the Nile Valley. In the heart of this plateau surface, two great depressions have occurred, Farafra and Bahariya depressions. The area of Farafra is more than 3000 km^2, and Bahariya has an area of about 1800 km^2. The Qattara—Siwa depression is considered to be part of a huge depression in the northern sector of the Western Desert.

II. **Eastern Desert**

The Eastern Desert occupied on the east border of Nile Valley and bordered by Suez Canal in the East with an area of about 223,000 km^2. This desert forms from a series of mountain chains (the Red Sea mountains), running parallel to the Red Sea and separated from it by a narrow coastal plain.

III. **Sinai Peninsula**

Sinai Peninsula occupies an area 61,000 km^2 in the northeastern portion of Egypt at South-West part of the Asian continent. The southern part of Sinai is formed of a complex of igneous and metamorphic rocks.

Climate

Climatic Regions

The Egyptian deserts is located in the hyper-arid regions of North Africa and lies in Asia astride the Sahara and the Arabian Desert with annual rainfall in most parts of less than 50 mm [1]. According to the aridity index P/ETP, the arid regions are classified to hyperarid ($P/ETP < 0.03$) and arid ($P/ETP = 0.03–0.20$). These classes are, in turn, subdivided according to the mean temperature of the coldest and the hottest month of the year. Consideration is also given to the time of the rainy period relative to the temperature regime. According to these bases, Egypt is distinguished into two climatic provinces, I. Hyper arid Province and Arid Province II as in (Figs. 2, 3 and 4) [1, 9].

I. Hyper arid Province and II. Arid Province. The hyperarid Province comprises three subprovinces: a. Hyperarid subprovince with mild winter and very hot summer: means of coldest and hottest months are 10–20 °C and >30 °C, respectively, which covers most of the Western Desert and the southern part of the Eastern Desert, b. Hyperarid subprovince with a mild winter and a hot summer (mean temperature of the hottest month = 20–30 °C) covering the Eastern Desert and the northeastern part of the Western Desert and Gebel Uweinat, and c. Hyperarid subprovince with very hot summer and very cold winter (<0 °C) prevailing in the montane country of the Sinai Peninsula [9].

The arid province comprises two subprovinces: the northern and southern: (a) The northern arid subprovince with winter rainfall which extends along the Mediterranean

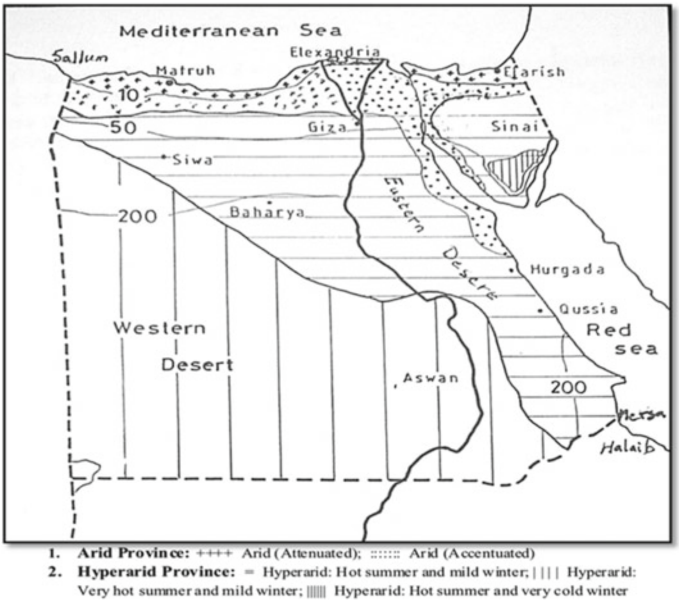

Fig. 2 Climatic Provinces in Egypt [1]

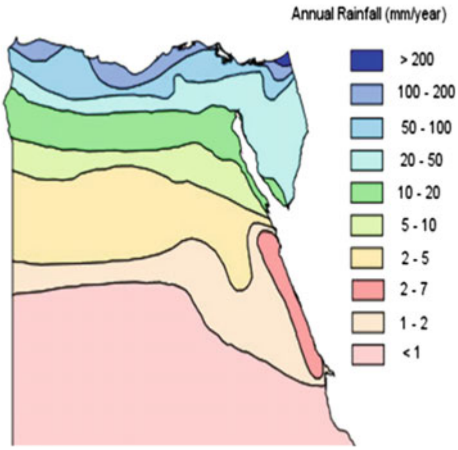

Fig. 3 Distribution of Rainfall in the Egyptian Deserts. (*Source* USGS GTOPOPO30; GADM global administrative areas; and UN Revision of World Urbanization Prospects.)

coast and Gulf of Suez. This subprovince is subdivided into 2 areas by UNESCO/FAO map of 1963: (i) the coastal area under the maritime influence of the Mediterranean sea with a shorter dry period (attenuated), annual rainfall may reach 200 mm and (ii) a more inland area with a longer dry period (accentuated), and an annual rainfall of 20–100 mm. Both areas are characterized by a mild winter and a hot summer. (b) The southern arid subprovince with a winter rainfall including Gebel Elba mountainous area of the Red Sea coast in the most southeastern corner of the Eastern Desert,

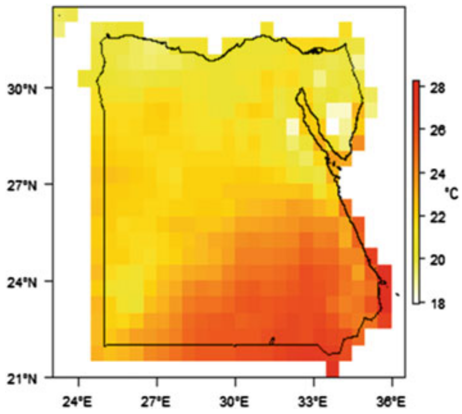

Fig. 4 Distribution of Temperature in the Egyptian Deserts. (*Source* USGS GTOPOPO30; GADM global administrative areas; and UN Revision of World Urbanization Prospects.)

here the annual orographic rainfall is significant where increase than 160 mm/year in Gebel Elba.

(i) Hyperarid provinces include all the area between Lat.22° and 30°N, except the coastal mountains along the Gulf of Suez. These are distinguished to:

- Hyperarid with a mild winter and a hot summer (mean temperature of the hottest month is 20–30 °C), this includes the Eastern Desert and the northeastern part of the Western Desert of Egypt, and Gebel Uweinat.
- Hyperarid with a cool winter (mean temperature of the coldest month is 0–10 °C), and hot summer, represented around the highlands of southern Sinai. Rain in hyperarid provinces is less than 30 mm/yr and is occasional and unpredictable.

(ii) The arid provinces include the northern section with winter rainfall, it extends along the Mediterranean coast and the Gulf of Suez. This section is distinguished into two provinces namely; –The coastal belt province under the maritime influence of the Mediterranean, with a shorter dry period (attenuated), –The more inland province with a long dry period (accentuated) and an annual rainfall from 20 to 100 mm. Both provinces are characterized by a mild winter and a hot summer. –The salient features of the main climatic variables in such provinces can be summarized in the following section.

Basic Climatic Elements

(a) Temperature Generally, summer is hot (mean of the very hottest month ranges between 20 and 30 °C), or very hot (mean of the hottest month is more than 30 °C). Winter is either warm (mean of the coldest month is 20–30 °C) or mild (mean minimum of the coldest month is 10–20 °C) expect on the highlands where the winter is cool with a mean minimum of the coldest month (between 0 and 10 °C).The temperature along the Red Sea coast varies between a mean minimum of the coldest month of about 10 °C towards the North and about 20 °C towards the South, and a mean maximum of the hottest month of about 33 °C towards the North and 40 °C towards the South. The range of variation becomes greater further inland (from about 4 to 38 °C in the oases of the Western Desert). In continental locations, temperature extremes of less than 4 °C in the coldest month (e.g. oases of the Western Desert) have been recorded. The coldest month is between December and February and the hottest month is between June and August in hyperarid and arid provinces, respectively (Fig. 4).

(b) Relative Humidity:

The relative humidity is influenced primarily by the relative nearness to the Mediterranean and the Red Sea. The most reduced records are those of inland areas of the parched and hyperarid provinces. The most noteworthy ones are those of areas closer to the Mediterranean coast. The most reduced records of relative humidity are by and large those of late spring, though the most elevated records are those of late autumn and early winter.

(c) Rainfall In general. Three precipitation belts may be recognized within the deserts of Egypt: (1) The Mediterranean coastal belt, (2) center Egypt with latitude 30°N as its southern boundary, and (3) upper Egypt. The first and second belts have a winter precipitation (Mediterranean regime). The stormy season expands from November to April, in spite of the fact that primarily concentrated in December and January. These belts compare generally to the attenuated and accentuated arid provinces of northern Egypt, where the normal annual rainfall ranges from 100 to 150 mm within the weakened parched territory, and from 20 to 100 mm within the accentuated arid province.

It expands south along the Gulf of Suez to Lat.26°N due to the orographic impact of the Red Sea coastal mountains. The third belt is nearly rainless; it compares generally to the hyperarid territories. Rain at this belt isn't an yearly repeating occurrence; 10 mm may happen once each ten a long time. The precipitation increments steadily to the North until comes to around 20 mm at the borders with the arid province (at Giza). One of the major highlights of precipitation in arid and semi-arid regions other than being meager, is its great temporal variability, the average deviation of annual precipitation from the mean, expressed as a percentage of the mean, is greatest in the hyperarid provinces (e. g. Siwa 83%). In the arid province the percentage variability is 65% at Giza which is close to the hyperarid provinces [1].

(d) Wind: In winter, the Sahara high-pressure system dominates the circulation and the northerlies bring cool dry air from the North Africa continental source region though occasionally the Arabian high brings warmer air to the eastern parts of Sudan. Both of these types are sometimes hindered by E-W depressions along the Mediterranean, and supplanted by cold dry air from the Eurasian landmass. In spring and autumn time, the Middle Arabian high is more overwhelming within the East, and the impact of Mediterranean depression is rarely felt, as air from both North Africa and the Arabian sources is considerably warmer than in winter. In Summer, the Saharan high is again dominant bringing hot dry air. Occasionally, very hot dust-laden winds blow (Khamaseen) which have numerous environmental consequences including possible effects on climate, soil formation, groundwater quality and crop growth. They may make issues counting considerable degrees of deflation and erosion [1].

Habitats

The environment can be broken down into a few essential units: biomes, ecosystems and habitats. A biome is like a city. An biological system is like a community in a city. There are numerous ecosystems in a biome. Each environment contains a number of diverse habitats. A habitat is like a home. There are many homes in an ecosystem. These habitats are the "homes" of the plant and animal species that live there. The hot desert ecosystem is the host of plants and animals which can be living in oppressive environments. This environment is represented by high solar energy, warm seasons throughout the year, little rainfall during winter, unpredictable rainfall, extreme variation in temperature between night and day as well as between winter and summer, and scattered vegetation. In this ecosystem, most plants are adapted to minimize the effects of too much solar energy. Plant annuals compress their life cycles and go dormant as conditions grow unfavorable [9]. According to [10], hot desert ecosystems cover all of Egypt and extend south to latitude 12 °N in Sudan. Such hot ecosystems are either arid or hyperarid and it is possible to distinguish between three main hyperarid and two arid provinces.

According to [11–19], the habitats in the Egyptian deserts are distinguished into the follow types:

I. **Gravel Formations**

It is a fluviatile deposit distinguished into two main classes:the gravel surfaces and the water runnels. The former comprises the flat gravel plains, the slops of gravel hills and the undulating surfaces of the gravel-covered mound and hillocks. The water runnels include the finer branches dissecting the gravel surface, the affluent branches receiving the water from the minor runnels, and the main channels collecting water from extensive catchment areas.

II. **Sand Formations**

The aeolian sand accumulation occupies an area of about 16% of the total surface area of Egypt. About 95% of this ratio is located in the Western Desert [20]. Sand formations represent a morphological feature of the coastal and inland deserts in both arid and hyper-arid provinces of Egypt [21, 22]. They vary in origin, size, height, structure, texture, water content and salinity. They may be categorized into: dunes, hillocks, hummocks, mounds and bars [22]. Psammophytes are plants that inhabit the sand formation, sand bars, sand hillocks and sand dunes which are usually associated with the lakes of the Oases and depressions [23, 24].