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Climate Change Impacts on Agriculture and Food Security in Egypt

Land and Water Resources—Smart Farming—Livestock, Fishery, and Aquaculture

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ISSN 2364-6934 ISSN 2364-8198 (electronic)
Springer Water
ISBN 978-3-030-41628-7 ISBN 978-3-030-41629-4 (eBook)
https://doi.org/10.1007/978-3-030-41629-4

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

With the writing of this preface, a long journey comes to an end, offering you glimpses of beautiful views. At the end of 2017, the idea of writing this book was conceived. One major motivation to write this book is the fact that the climate change impact is increasingly attracting the world's attention. Does this really happen? If so, how much of it is because of human activity? How far will climate change adaptation be possible? What action can or should we take to fight it? How much is that going to cost? Or is it too late to take useful action already? This book aims to provide answers to all these questions by providing the best and latest available information.

The current generation's primary concern is the undesirable changes taking place in global warming and global climate and environment. There is nothing permanent. We all know that it is imminent to change. Why are we so alarmed by the global climate change? Climate change writing often falls into one of two opposite traps, both of which could be are avoided by applying the ideas of this book. This is not a story of gloom and doom, of the inevitable catastrophe of the climate. On the contrary, it outlines, in more detail than usual, what can and should be done to prevent real disaster risks. It is also not, however, a story of complacent congratulations on "win-win" policies, cautiously incremental steps, and "green" policy choices. It calls us to an endeavor worthy of the twenty-first century's resources and ingenuity, to bold initiatives with large costs—and far greater benefits. Climate change has become, as well as one of the most dynamic, the defining environmental legal and political challenge of the twenty-first century.

This book is written to help us make sense of the climate change discussion, especially on the question of whether this problem can be solved. It is now widely accepted that our climate has changed and will continue to change due to our economy based on fossil fuel, our transformation of the surface of the planet, and the increasing number of people and their growing wealth. Nevertheless, there is increasing confusion about the solutions. Some people think the only way is to drastically change our way of life. Give up our cars; give up our heating, no air travel anymore. Return to the Middle Ages, some people think that in the near future, technology will give us plenty of CO_2-free energy at low cost. Others

believe that nuclear power is the only solution, as renewable energy and energy efficiency will never significantly reduce CO_2 emissions. Others believe that nuclear power is the only solution, as renewable energy and energy efficiency will never significantly reduce CO_2 emissions. Therefore, the key message of this book is intended to deserve widespread attention to the idea that "The climate and development crises will be solved together, or not at all. Moreover, the faster we begin, the less painful—and more possible—the solutions will be." The fact that we can control climate change is what our current knowledge tells us. We cannot avoid further changes and further negative impacts altogether, but we can avoid the most severe impacts of climate change, so that things remain manageable. We want people to understand that and see that this is only possible if strong and decisive action is now being taken.

This book's goal is to introduce the role of ecosystems in the climate system and the changing Earth system. The book consists of 25 chapters and contributed by more than 35 scientists, specialists, and researchers from Egypt. Keeping in mind the philosophy of "The Art of Climate Change," chapter "Introduction to 'Climate Change Impacts on Agriculture and Food Security in Egypt'" gives an overview of climate change impacts on agriculture and food security in Egypt as it presents the main technical issues of the chapters. The book begins with an overview of our knowledge of the climate system, the changes taking place, the opportunities for further climate change, and the impact on human and natural systems. Briefly, it gives the rationale for the rest of the book on how to control climate change and limit it to manageable proportions.

The 23 main chapters of the book are roughly organized in five main parts, which sequentially observe the climate change impacts on agriculture and food security in Egypt. A brief description of each of the part is as follows:

The first part is organized to present a comprehensive overview of climate change in Egypt. This part consists of three chapters. Two ways were identified to give us an overall impression of climate change in Egypt. The first way is linked to governance and institutional structure of climate change in Egypt. The second way is the role of science, technology, and innovation in addressing climate change challenges in Egypt.

The second part, which consists of five chapters, delves deeply into the land and water resources concepts. This part covers five potential impacts, which were identified to study the effect of climate change on land and water resources in Egypt. First is the effect of climate change on agriculture, which has specifically become a global issue due to the ever-growing need to provide food security and end hunger. Second are the impacts of climate change on microbial activity in agricultural Egypt's soil. The third influence is through the mapping of Egypt vulnerability to sea level rise. Fourth inspiration is soil itself as driver and victim of climate change. The final control is through soil carbon sequestration for climate change mitigation.

The third part, which involves three chapters, reviews the various smart farmings. This topic is covered in detail in seven approaches, which were identified acknowledged for using smart farming as a way to mitigate climate change impacts

on agriculture. The first is assessing vulnerability and enhancing adaptive capacity and resilience to climate change; second, the pollination of flowering plants is one of the most important ecological services in natural and agricultural ecosystems; third, change of agricultural calendar as a response to climate variability; fourth, projected crop coefficients under climate change in Egypt; fifth, rice production in Egypt: the challenges of climate change and water deficiency; six, smart farming approach is using nanotechnology for real-time control of the red palm weevil under climate change; and finally, how to face climate change: urban gardening and sustainable agriculture are discussed.

The fourth part, which contains five chapters, discusses the different methods and approaches for livestock, fishery, and aquaculture. Five different ways are recognized for potential climate change impacts on livestock, fishery, and aquaculture. First, potential climate change impacts on livestock and food security nexus in Egypt is presented; second, the influence of climate changes on animal feed production; the third way is through algae and fish; the fourth way is climate change impact on immune status and productivity of poultry as well as the quality of meat and egg products; and the final way in this book is climatic change and chicken immunity.

The final part, which consists of three chapters, provides a comprehensive overview of the socioeconomic impacts and green sustainability. Three scenarios have been identified to study the socioeconomic impacts of climate change. The first scenario deals with agriculture and rural communities' vulnerability in the Nile Delta. The second scenario is related to water–climate–food nexus for green sustainability. The third scenario is an efficiency analysis approach.

Lastly, the final chapter briefly summarizes the most significant findings and recommendations of the book. The concluding chapter highlights major challenges to achieving equitable and sustainable water security in Egypt and offers cautious prospects for the future.

At this point, this book on the impacts of climate change on agriculture and food security in Egypt emerged. There are several books written around the world on the topic; however, this book aims to highlight and focus on recent advances in the impacts of climate change on agriculture and food security in Egypt. A group of experts has come together to write this book, which aims to pass on the new knowledge and information available to the readers. Depending on your interests and preferences, one can start the journey from anywhere. Readers and beneficiaries vary from academics, professionals, and scientists to students from undergraduate to graduate.

This book is intended to be of interest to all stakeholders in the climate change sector: financing institutions, users' associations, planners, designers, training, and research institutions. I wish it would act as a guide book on climate change for those interested readers. We believe the information presented here will be of the greatest help policy-makers, managers, and researchers interested in a broad perspective of urgent climate change issues in Egypt and hope that the book will contribute to some real if modest, progress toward the beneficial management of climate change.

Without the great efforts of all the authors, advances in this book would not have been possible, and I am sure that their valuable contributions will increase the significance of the book. To meet Springer's high-quality standards, it would not have been possible to produce this book and make it a reality without their patience and effort in writing and revising the various versions. All appreciation and gratitude must be extended to include all members of the Springer team who have worked long and hard to make this volume a reality for researchers, graduate students, and scientists worldwide. I have to thank all the experts who contributed to the chapter review processes. I hope it has widely read. If we want to avoid past misunderstandings, then we need to change direction and start taking advantage of the knowledge base of scientists. We did not have that opportunity a decade ago. Now it is the right time.

The editors strongly welcome to receive feedback and comments from the audiences to improve the future editions.

Ismailia, Egypt — El-Sayed Ewis Omran
Zagazig, Egypt — Abdelazim M. Negm
May 2019

Contents

An Overview of Climate Change in Egypt

Introduction to "Climate Change Impacts on Agriculture and Food Security in Egypt"

El-Sayed Ewis Omran and Abdelazim M. Negm

Abstract This chapter introduces briefly the main technical components of the chapter presented in the book. The technical contents of the chapters are presented theme-wise arrangement. The book contains 25 chapters arranged under five themes to covers different topics associated with climate change impacts on agriculture and food security in Egypt.

Keywords Climate change · Egypt · Climate variability · Land and water resources · Smart farming · Livestock · Fishery · Aquaculture · Socioeconomic impacts

1 Background/Overview

The current generation's primary concern is the undesirable changes taking place in global warming and global climate and environment. There is nothing permanent. We all know that it is imminent to change. Yet why are we so alarmed by the global climate change? Climate change writing often falls into one of two opposite traps, both of which could be are avoided by applying the ideas of this book. This is not a story of gloom and doom, of the inevitable catastrophe of the climate. On the contrary, it outlines, in more detail than usual, what can and should be done to prevent real disaster risks. It is also not, however, a story of complacent congratulations on "win–win" policies, cautiously incremental steps, and "green" policy choices. It calls us to an endeavor worthy of the twenty-first century's resources and ingenuity, to bold initiatives with large costs—and far greater benefits. Climate change has become,

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E.-S. E. Omran and A. M. Negm (eds.), *Climate Change Impacts on Agriculture and Food Security in Egypt*, Springer Water, https://doi.org/10.1007/978-3-030-41629-4_1

as well as one of the most dynamic, the defining environmental legal and political challenge of the 21st century.

This book is written to help us make sense of the climate change discussion. Especially on the question of whether this problem can be solved. It is now widely accepted that our climate has changed and will continue to change due to our economy based on fossil fuel, our transformation of the surface of the planet, and the increasing number of people and their growing wealth. Nevertheless, there is increasing confusion about the solutions. Some people think the only way is to drastically change our way of life. Give up our cars; give up our heating, no air travel anymore. Return to the Middle Ages, some people think that in the near future, technology will give us plenty of CO_2-free energy at low cost. Others believe that nuclear power is the only solution, as renewable energy and energy efficiency will never significantly reduce CO_2 emissions. Therefore, the key message of this book is intended to deserve widespread attention to the idea that "The climate and development crises will be solved together, or not at all. Moreover, the faster we begin, the less painful—and more possible—the solutions will be." The fact that we can control climate change is what our current knowledge tells us. We cannot avoid further changes and further negative impacts altogether, but we can avoid the most severe impacts of climate change so that things remain manageable. We want people to understand that and see that this is only possible if strong and decisive action is now being taken. The recommendations given under the different themes of the book in chapter "Update, Conclusions, and Recommendations to "Climate Change Impacts on Agriculture and Food Security in Egypt" can guide taking such decisions.

2 Themes of the Book

Such climate change will affect Egypt's natural resources, particularly the major resources characterized by the relative scarcity of Egypt's land and water resources. This leads to a direct and far-reaching impact on the agricultural sector and thus on the food security of Egypt. The four dimensions of food security include climate change: food availability, access, capacity, and stability. So, the objective of the book is to address the following main theme.

- An overview of climate change in Egypt.
- Land and water resources.
- Smart farming.
- Livestock, fishery, and aquaculture.
- Socioeconomic impacts.

The next sections present a summary of each chapter presented in the main body of the book under its related theme.

3 Chapter's Summary

The following subsection presents the salient features of the chapters presented in the book under each theme of the book.

3.1 An Overview of Climate Change in Egypt

This section is covered in four chapters from 1 to 4. Chapter two is titled "An Overview of Paleo-climate Evidence in Egypt". It explains how can the knowledge that we can get from the past can help us to understand the consequence of the current warming. The earth system is a closed system has its energy from the solar and cosmic rays and formed of four interconnected spheres (lithosphere, atmosphere, hydrosphere, and biosphere). The change in chemical or physical conditions in each one of these sphere is monitor directly for the others. Several internal and external processes have a strong effect on modifying the earth climate such as extraterrestrial impacts, volcanism, and injection of greenhouse gaseous into the atmosphere, these processes are recorded in the geologic history of the earth as a catastrophic and/or hyperthermal events. The ecosystem has three different ways to respond to the climate change; extinction and it is the worst response and is recorded several time in earth history five of them were major mass extinctions; evolution, in which the Genera are adapting themselves to the new climatic condition; or rising of new genera. In several cases, these three scenarios are recorded together in other only one or two of these scenarios can be observed. To sum up, the study of the paleoclimatic changes that prevailed in the earth's history is an important issue to understand the current climatic changes. Some extinction and hyperthermal events can be used as an analog for the current changes and help to predict what the future hide for the humankind.

While chapter three is about "Governance and Institutional Structure of Climate Change in Egypt" focuses on the effective implementation of climate change policies and strategies in Egypt which requires strong governance and institutional structure. More coordination between the different stallholders and more effective involvement of the private sector and civil society organizations in the climate change implementation plans are required.

Successful climate change governance systems should ensure the implementation of climate policy integration at the national level. This chapter address the governance and institutional structure of climate change in Egypt listing the different institutions that are partners to the Egyptian Environmental Affairs Agency (EEAA) handling the issues related to climate change in different ministries and sectors in Egypt. The chapter also covers the environmental policies and legislation in Egypt starting from the Law 4/1994 as the first environmental protection law in Egypt, listing all related laws as well as the already implemented projects. The chapter also discusses the important role of civil society organizations and their active engagement as has been

highlighted in the Third Communication of Egypt (2016). Also, the challenges facing the private sector have been discussed. The chapter also reflected on the issue of gender mainstreaming in the climate change policies in Egypt heightening the importance of the development of the National Strategy for Mainstreaming Gender in Climate Change in Egypt. The chapter also covers the engagement of Egypt in the regional and global climate change governance focusing on being the president of the African Ministerial Conference on the Environment (AMCEN) and Coordinator of the Committee of the African Heads of State and Government on Climate Change (CAHOSCC) for the period 2015–2017. Also, the chapter discussed the main challenges facing climate change governance in Egypt highlighting the need for better coordination between different stockholders.

The second way is linked to governance and institutional structure of climate change in Egypt. There is still a marked lack of support for the growth of institutional capacity and the frameworks needed to address climate change at local [1, 2]. A cross-cutting problem, such as climate change, can not be handled by a single department of government or ministry. The inclusion of climate change in policy decisions requires consideration of the causes and consequences of climate change in non-climate sectors [3]. "Integrated strategies are a relatively novel approach to govern highly complex issues that involve several sectors and levels of governance. These are a key tool for fostering not only sustainable development, but also convergence or ecological modernization of environmental policy" [1]. Both concepts promote the integration of environmental concerns into sectors with significant environmental implications long before sustainable development dominated the discourse on the environment [4]. In Egypt, despite a stated commitment to grassroots involvement in climate change adaptation processes and actions, the actual focus in national adaptation plans is on technical and infrastructure options for adaptation, with little attention given to the social and institutional context in which these options operate [2]. In order to better serve the needs and interests of the most vulnerable populations, future national-level efforts to develop adaptation plans need to consider the role of local institutions more centrally.

Chapter four elaborates on the "Role of Science, Technology, and Innovation in Addressing Climate Change Challenges in Egypt" because climate change becoming a serious man-made environmental challenge with its serious impact on the livelihood. It provides them with the tools and technologies needed to address the impact of climate change, which should be the main task of international communities [5]. Therefore, science, innovations, and technologies are being to be more important than ever. They have been focused by agricultural research initiatives that contribute to the climate change adaptation efforts and enable the farmers and policy-makers to draw their strategies and actions to face climate change impacts. Egypt vision 2030 stated that "Knowledge, innovation, and scientific research contribute to achieving the goals of sustainable development and to cope with the impact of climate change on agricultural sectors, new technologies and innovations have been tested and verified by agricultural research initiatives that contribute to the climate change adaptation efforts and enable the farmers and policy-makers to draw their strategies and actions to face climate change impacts. The Egyptian research system is making great effort

to overcome challenges related to innovation, and scientific research and already making big progress with regards to assessment of the climate change impact on Egyptian agriculture as well as suggesting scientific climate change adaptation measures Because of the cost of research, funding for scientific research and development needs long-term commitments which are not affected by rapid policy changes. There is also a need for more international cooperation.

3.2 Land and Water Resources

This theme is covered into five chapters. The chapter titled "Impact of Climate Change on Plant-Associated Fungi" discusses an important aspect related to climate change which is its impact plant-associated fungi. The chapter features the relationship between climate change and the diversity of soil fungi such as decomposers, mutalists, and pathogens. Since climate change directly affects abiotic stressors such as temperature, humidity, drought, salinity and nutrient limitations, the relationship between plants and mycorrhizal fungi is discussed and linked to the increase in agricultural productivity. The increase in temperature and carbon dioxide directly affects the activity of saprophytic and pathogenic fungi, consequently leading to change the soil fungal profile. The effect includes fungal enzymatic activity as well as secondary metabolites and eventually have an overall effect on soil mycobiomes. In order to reach precision farming, the state of the art technologies has to be used. Modern tools such as Global Positioning Systems (GPS), Geographic Information Systems (GIS) and Wireless Sensory Networks (WSN) offer precise monitoring for key biomarkers. WSN is gaining attention because it can be coupled with corrective action providing a fair opportunity to mitigate harsh climatic changes.

While the chapter titled "Impacts of Climate Change on Microbial Activity in Agricultural Egyptian Soils" is devoted how climate change affects the microbial processes and activity of enzymes in Egyptian soils and how they are used as an indicator of their quality and are likely to respond rapidly to climate change. Egyptian soils have a great diversity of microorganisms such as bacteria, actinobacteria, fungi, and arbuscular mycorrhizal fungi that play a vital role in nutrient cyclings, the breakdown of soil organic matter, and increasing soil fertility. However, we still have no general framework or know remarkably little about their response to climate change. Moreover, the soil is a complex habitat for microbial growth, and the structure and function of microorganisms are tremendously complex in the soil. These complexations lead the difficult to predict the effects of climate change on the activity of Egyptian soil microorganisms. In this chapter, we review the currently available researches regarding the impact of climate change on soil microbial activities such as microbial populations, microbial biomass, enzymes activity, soil beneficial microorganisms in Egyptian soils.

Climate change is possible to change the composition, function, and abundance of soil microorganisms, as well as plant-microbe interactions that together affect the quality of soils. Microorganisms inhabiting Egyptian soils have been exposed to

high temperature and accumulating of carbonates and soluble salts in desert soils, and the other inhabiting in alluvial soils in the Nile Delta and the Qattara Depression of the Western desert. Soil microbial activity will affect by climate change directly or indirectly. These effects include increasing temperature, elevated or increasing the concentration of CO_2, rise changing soil moisture content, increasing of soil salinity, and drought. The activity of soil microorganism and/or enzyme is significant as a sensitive indicator of soil biological quality. These activities are informative to determine changes in soil biochemical properties that are affected by environmental stress from natural phenomena or anthropogenic activities. Bacteria and fungi living in the soil control the breakdown of organic matter in the soil and its release into the atmosphere as carbon dioxide [6]. Climate warming is expected to increase soil microbe development, promote more CO_2 release, as well as positive climate change feedback. A better understanding of microbial processes is likely to improve climate change predictions [7]. Recent research has therefore attempted to quantify the impact of warming on soil microbes and the carbon cycle processes they control and to explain this using efficiency metrics such as microbial carbon [6].

The third chapter under the current theme is titled "Soils as Driver and Victim of Climate Change in Egypt". This chapter explains how the soil can act as a driver and Victim of climate change. Agricultural soil is an important driver of GHG emissions. Emissions from clay soils are higher compared to sandy soils, especially in the presence of high moisture and organic matter contents and high pH that encourage CO_2 and N_2O flux. Global warming increases CO_2 emissions with an exponential relationship by increasing the temperature of the surface layer of agricultural soils. Nitrogen fertilizers are a major source of N_2O emissions both in dry soils due to nitrification process or denitrification in waterlogged soils as well as methane emissions in rice fields. In Egypt, about 25 million tons of rice husk and sugarcane wastes are burned in open field, which contributes strongly to climate change.

On the other hand, agricultural land is a victim of climate change as the global warming accelerates the breakdown of soil organic matter, which reduces soil fertility, water storage, and microbial activity, destroys soil structure and increases their susceptibility to soil compaction. The surface layer of soil is expected to lose about 55 million tons of carbon by the year 2050. Egypt's agricultural land is experiencing increased drought throughout the country. Northern coasts of the Delta are intruded by rising sea level, and salt-affected soils cover about 10% of the Delta area.

On the other hand, the chapter titled "Soil Carbon Sequestration for Climate Change Mitigation: Some Implications to Egypt" show how in carefully managed croplands, soil C sequestration can be substantial and represents a potentially constructive portion for mitigating the increased levels of atmospheric CO_2. The soil is the largest terrestrial carbon (C) stock, and those factors that affect C retention and release also influence on atmospheric CO_2 levels. Soil C sequestration represents about 90% of the total mitigation practices of climate change and about 10% of emission reduction. There is a great concern of soil carbon (C) sequestration and its role in absorbing atmospheric CO_2 not only because of its impacts on climate change mitigation but also because of its positive impacts on the sustainability of crop productivity, soil fertility, and soil quality. Cultivation has resulted in considerable loss

of soil C due to chemical and biological decomposition of soil organic carbon (SOC), as well as erosion by wind and water. There is a general agreement that many agricultural ecosystems have a huge potential to sequester carbon in the soil, which could decrease CO_2 concentrations in the air and mitigate its global emissions. Egyptian soils are low in their C content. Thus its potential to sequester C is high. Therefore, good management practices should be considered for enhancing soil C sequestration in Egyptian soils, especially in degraded and desert soil. Climate change is indicated as an increasing trend in atmospheric temperature and global changes in weather conditions [8].

Climate change's effect on global SOC stocks has recently been widely recognized [8].

Moving from the soil to the sea, the chapter titled "Mapping Egypt Vulnerability to Sea Level Rise Scenarios" is presented to highlight the threat of sea level rise on the Nile Delta and present a methodology to develop a web vulnerability mapping tool using Geographic Information Systems to study the different sea level rise scenarios and to identify and map the areas that are most vulnerable to SLR on the Nile Delta coast. Four scenarios are implemented to assess the impact of SLR, for 25, 50, 75, and 100 cm.

The Nile Delta shoreline extends from Alexandria in the west to Port Said in the east, with a total length of about 285 km. The Nile Delta region in the Mediterranean coastal zone represents the major industrial, agricultural, and economic resource of the country. The region is characterized by relatively low land elevation, which leaves it severely exposed to rising sea levels. In addition, it suffers from local land subsidence, compounding the effects of rising seas (https://www.stimson.org/sites/default/files/file-attachments/Mohamed_1.pdf). This area is subject to shoreline changes resulting from erosion and accretion, subsidence, and sea level rise resulting from climate change.

In order to investigate and analyze such environmental problems and their impacts, we must have a tool (SLRS) to understand these changes. The SLRS is a web mapping tool based on the assessment of the IPCC definition of vulnerability. National and subnational geographic and socio-economic data have been gathered for the area of study from different sources including Shuttle Radar Topography Mission (SRTM), land cover, urban areas, industrial zones, protected areas, power plants, and population data.

3.3 Smart Farming

The smart farming theme is covered in 7 chapters. The chapter titled "Agricultural Production in Egypt: Assessing Vulnerability and Enhancing Adaptive Capacity and Resilience to Climate Change" address the challenges facing the agricultural production in Egypt due to climate change in the context of the impact of climate change on the agricultural and water sectors globally and at the regional levels. The international community has endorsed five principles of sustainable food and agriculture in

order to implement the 2030 Agenda, which provide a framework for policy dialog and the development of appropriate policies, strategies, regulations and incentives [9]. More than 40% of the Arab population has already been exposed to drought and other climate disasters [10]. The chapter also discusses the definition of the term vulnerability in general, analyze the vulnerability of the Near East and North Africa Region to climate change due to its limited natural resources of water scarcity and land degradation, that will be even worse by climate change providing detailed information on the impact of climate change on different farming system in the Arb Region and the regional efforts including the " Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region' (RICCAR)". The chapter also provides a summary of the farming system in Egypt and its vulnerability to climate change focusing on the water resources (the Nile, rainfall and the groundwater) as well as the impact of climate change due to expected sea level rise and changes in the ecosystems of the lakes in the Nile Delta. The chapter also discusses the vulnerability of both crop and livestock production systems in Egypt as well as the fishery production system providing an estimation of the change in the crop, livestock and fishery production and the impact of that on the small scale farmers in Egypt. The chapter also discusses the strategies that have been developed by the Egyptian government to enhance the adaptive capacity and resilience to climate change including "Egypt vision 2030" and the climate change adaptation efforts undertaken by the government.

The second chapter under the smart farming theme is titled "Vulnerability of Crop Pollination Ecosystem Services to Climate Change". The chapter explains how climate change threatens the ecosystem services, especially crop pollination, as a result of its impact on the biodiversity of pollinators, reduces crop productivity, and negatively impacts global food security. In Egypt, over the last 20 years, due to the increase of temperature, a lot of impacts have affected the agriculture ecosystem, especially to flora and fauna, including wild and domestic bees. This led to the disappearance of some species, and some other species have become more superior for dominating in the ecosystem. In the future, it is expected that there will be increasing impacts. Beside the impact of climate change in Egypt, several bee species are threatened by nesting fragmentation, habitat elimination, degradation, and urbanization. Climate change is also expected to have some more changes in the bee generations and their intercorrelations with their foraging resources. There is evidence that many parasitic mites, diseases, and pathogens have a great impact on the managed honey bee colonies across Egypt, which probably the factors are leading to Colony Collapse Disorder (CCD). Pesticides also are a key factor behind colony collapse disorder (CCD), directly and in tandem with two leading co-factors, pathogens, and a shortage of natural resources. Climate change and human interference such as miss management of honey bee races have a great influence on the spreading and weakness of honeybees. Recently, there is a lot of efforts for protecting and conserving plant pollinators with a particular interest with honey and solitary bees. In Egypt, many efforts are ongoing for protecting the habitats of some solitary bees present in Egypt. These attempts have already succeeded in re-nesting and establishing three bee species.

Several efforts must be taken into consideration such as enhancing the health of pollinators "honeybees and solitary bees," avoid extensive using of chemical pesticides, encourage local farmers for cultivating bee-friendly plants and protecting the natural nesting habitats of solitary bees. Promote the ecological intensification strategy such as intercropping, crop rotations, farm-level diversification, and reduced agrochemical use for promoting biodiversity beneficial to agricultural production. Therefore, it is strongly recommended to mitigate the potential adverse impacts of climate change on the diversity and efficiency of insect pollinators, especially, managed honeybees and other solitary bee species.

The third chapter in this section is titled "Change of Agricultural Calendar as a Response to Climate Variability". It demonstrates the need for farmers to adjust their agricultural calendar and switch to farming practices that make better use of natural resources. Climate change often has an indirect impact on agricultural production by affecting the development and distribution of crop pests and animal diseases, increasing the rate and spread of harmful diseases, weather conditions, decreasing water supply and irrigation, and increasing soil erosion severity. Important agricultural adaptation methods include new crop varieties and animal species suitable for drier situations, irrigation, crop divarication, implementation of mixed crop and livestock farming systems, and changes in the dates of agricultural activity. In response to short-term climate variability, some of these methods (e.g., changes in agricultural activity dates) are classified as coping responses. Many factors and critical information, including plant calendars, are considered [11]. In its growth cycle, the sequential series of various phenological stages of a crop determines the so-called crop calendar [12].

Crop calendars provide the timing of crop sowing, growing, and harvesting periods. Different sources of information were used on crop calendars. There is no research focusing on how farmers in the face of climate change are adapting their entire agricultural calendar. Thus, as a response to climate variability in Egypt, this chapter aims to explore observed changes in the agricultural calendar. It also aims to illustrate the factors affecting the decision of farmers to adjust their agricultural calendar as a climate variability coping mechanism.

Land surface phenology (LSP) metrics were used as a default for crop calendars and criteria such as the beginning and end of the season were applied to identify the pixel-level growth period of active agricultural vegetation.

The chapter titled "Projected Crop Coefficients Under Climate Change in Egypt" addresses the quantification of how climate change will affect the values of crop coefficient (Kc) for several important crops in Egypt in 2030 as this is very important in the management of water resources in the future. Projection of Kc values for the cultivated crop is important for the future planning of water resources. The available weather data in 2030 contained only solar radiation and temperature (maximum and minimum), which not enough to calculate evapotranspiration (ETo) using the Penman-Monteith equation (P-M). To overcome that, the monthly values of ETo in 2016 were calculated using the Penman-Monteith equation (P-M) and Hargreaves-Samani equation (H-S). Then, the monthly ETo (H-S) values were regressed on the

monthly ETo (P-M) values, and prediction equations were developed for each agro-climatic zone of Egypt. These equations were used to project ETo values under climate change in 2030 using RCP6.0 climate change scenario resulted from MIROC5 climate change model. The developed ETo values were used to run BISm model and to calculate Kc values for 14 field crops, 7 fruit crops, and 13 vegetable crops, where the date and the value of each Kc growth stage, as well as the water consumptive use of each crop in 2030 were calculated. Comparison between Kc values in 2016 and 2030 for field and vegetable crops revealed that the values of Kcini were higher in 2016, compared to its counterpart values in 2030. The values of Kcmed and Kcend were similar or lower in 2016, compared to its counterpart values in 2030. Whereas, there was no change in the values of Kc for fruit crops between 2016 and 2030.

A practical example is given by the chapter titled "Rice Production in Egypt: The Challenges of Climate Change and Water Deficiency". This chapter show how the changing in rice management practice; such as decreasing ploughing, creating another alternative to rice straw burning and balanced fertilizer application would lead to mitigating of greenhouse gas emission from rice cultivation and improving soil organic matter (SOM) stocks, subsequently soil quality and productivity. Climate change has been one of the major global environmental problems of the 21st century. Rice is the main cereal crop for over 50% of the world's population. Rice cultivation is known as an important emitter of greenhouse gas emission, especially methane due to rice management practices and burning of rice straw after harvesting. However, many studies confirmed that rice soils accumulate carbon higher than other crops such as wheat and corn. The cultivated area of rice in Egypt is approximately 650,000 ha from the whole cultivated area in Egypt; approximately 3.3 million ha; i.e. around 20% of the cultivated area in Egypt. Egypt relies on the Nile for 97% of its water requirements. The expected scenario of water deficiency in the Nasser Lake due to the Grand Ethiopian Renaissance Dam construction, with pulling of deficiency from Dam Lake; is emphasizing on wasting approximately 1.7 million ha of Egypt's cultivated area. As well, the expected high scenario of a relative sea level rise in Egypt; especially Nile Delta increases the amount of land that lying under risk from inundation in the north Nile Delta by 300 km^2, which estimated by one-fifth of the total agricultural land in the northeast Nile Delta only. Also, all crops are projected to have a decrease in yields and an increase in irrigation needs. Thus; all these challenges will increase the stresses on rice production and decrease soil C storage in Egypt as a result of climate change and water shortage due to establishing GERD.

On the other hand, the chapter titled "Nano-technology for Real-Time Control of the Red Palm Weevil Under Climate Change" explains how to utilize the nano-techniques using acoustic and thermal sensors, to detect the infection of RPW at early stages and consequently protect the Red Palm Weevil. In fact, the current measures used to control the insect are not effective enough to succeed in eliminating the insect because of the great difficulty in early detection of infection and reaching all life stages inside the trunk. The first objective of this study is to detect the presence of living stages of RPW, which are hidden in the palm tree. Nano-sensor system using acoustic and thermal sensors was developed for significant recognition of RPW in an earlier phase of the infestation.

The second objective was to propose Nano-natural (plants and minerals) extract for RPW treatment and cure. Nano-minerals were used and prepared in natural leaves extract to control RPW, which is a cost-effective and environmentally friendly method. The nanoparticle minerals were used and prepared in *Moringa oleifera* leaves extract to control RPW. Nano-minerals extract (NME) drastically decreased developmental stages of *R. ferrugineus*. The compound is a 100% natural solution. It is derived from natural plants and minerals that can significantly aid in controlling RPW. Also, it is safe to use on all plants and crops including natives.

The third objective was to propose a Nano-ultrasonic system to prevent the date palm field from infected RPW. Ultra-sonic sensors were used to prevent the RPW to attack the date palm trees. Unlike traditional methods, which are time-consuming, and labor intensive, this system offers the advantages of keeping the palm trees intact; reduce costs, as well as saving time and money in the process of pest's infestation detection.

The smart farming theme ends with the chapter titled "Facing Climate Change: Urban Gardening and Sustainable Agriculture" to demonstrate how every person or every official in the municipality or community can play a role in mitigating climate change. Either by reducing emissions from his activities or by reducing the levels of incoming emissions through sustainable gardening. Managers must follow the right scientific methods for choosing the appropriate garden plants or following the agricultural practices that reduce emission levels. Measures to combat climate change encompasses two primary titles: removal of the maximum greenhouse effective gases and decreasing causes of greenhouse gas emissions. The direct greenhouse gases are carbon dioxide, nitrous oxide, and methane. Nitrous oxide is approximately 300 and methane around 30 times than carbon dioxide at trapping heat in the atmosphere. Climate change affects and is affected by all communities, but its treatment must begin with the actions of individuals. Trees in the urban area strongly reduce pedestrian level heat stress by absorbing and reflecting solar irradiance.

Vegetation in gardens is one of the most important components affecting climate change. Urban gardening, mainly consist of trees resource, is a valuable asset. Trees' benefits to the human being were most pronounced in their contribution to environmental benefits. Thus, plants in gardens were found to provide a particularly important function in mitigating climate change and maintaining the environmental quality of communities.

Gardeners can help lessen the global warming pollutants associated with waste disposal by turning leaves, grass, woody garden clippings, and dead garden waste into mulch or compost, then using it in the garden. Recycling these wastes will not only reduce methane emissions from landfills but also improve the garden's soil and help it store carbon. One of the innovative methods that reduce greenhouse gas emissions is to make and use biochar. Because nitrous oxides are an important greenhouse gas, better management of nitrogen fertilizers can reduce its emissions. The four main management factors that help reduce nitrous oxide emissions from applied nitrogen fertilizer are commonly known as the 4R's: right application rate; right formulation (fertilizer type); right timing of application; right placement at the plant's root zone as possible.

3.4 Livestock, Fishery, and Aquaculture

This theme is covered in 5 chapters. The chapter titled "Potential Climate Change Impacts on Livestock and Food Security Nexus in Egypt" illustrates the interactions between and among the energy, water, land, and climate systems that take place within a social and economic context. Regardless of the way that the phenomenon of worldwide atmosphere changes, and the local effects, it is normal that Egypt would be one of the countries most influenced by the impacts of climate change. These impacts are reflected in high temperatures, changing rainfall pattern, rising sea levels, and the expanding recurrence of atmosphere related disasters, which posture dangers to farming, agriculture land, water supply, and food security. Agriculture land is a constrained that ought to be utilized effectively and in a way that keeps up its esteem with the goal that it can produce an adequate amount of food, fuel, and forage in both the short and long term. To enhance rural life and enhance the food security in the district, it will be fundamental, subsequently, to enhance the efficiency of this agricultural framework through presenting water and soil preservation procedures, providing quality seeds, and empowering the utilization of manure. From the viewpoint of water administration, intercessions to increment agricultural profitability ought to incorporate projects to extend irrigated areas, enhance the water-maintenance properties of soil, and enhance profitability and water-utilize efficiency. To enhance production, and accordingly, farmers, population, and food security are the two primary components prompting the expansion and the requirement for more developed agribusiness in both rainfed and irrigated farming.

Added to the above, the chapter titled "Influence of Climate Changes on Animal Feed Production, the problems, and The Suggested Solutions" presents the efforts done by some selected countries across the world to get the benefit of how the climate change influenced the animal feed production. Climate change is a long-term change in the earth's climate, especially a change due to an increase in the average atmospheric temperature. Climate change demonstrates itself through the noticeable variation in the weather, including temperature, rain fall, and wind. Agriculture in the arid land is vulnerable to climate changes since it depends on water resources and prevailing atmospheric conditions. The influences and consequences of these variables on agriculture might operate negatively or positively. There is a reciprocal effect between climate change and animal production. The production of livestock contributes about 18% of global greenhouse gas emissions from all human activities. The farm animals are prone to the adverse impacts of the changes in climate.

The changes in climate will impact both of the quantity and quality of forage production as well as their reliability. Major impacts of climatic changes on feed crops and grazing systems would be changes in herbage growth, changes in the composition of pastures, changes in herbage quality, and the offset of biomass yield increases. Since pastures depend on rainfall, any changes in rainfall patterns will affect the plants on pasture.

Climate Change Convention in Paris and declared an agreement to "hold the increase in the global average temperature to well below 2 °C above pre-industrial

levels… recognizing that this would significantly reduce the risks and impacts of climate change", pursue efforts to limit the temperature increase even further to 1.5 °C and undertake and communicate ambitious efforts to contribute to the global response to climate change by strengthening the mobility of countries to deal with the impacts of climate change.

Moreover, the chapter titled "Algae and Fishes: Benefits and Hazards" show how algae play a major role as primary producers and form the base of the food chain as they are the major diet for many aquatic animals. They are either microscopic or macroscopic, and both can be cultured for mass production of fish and crustaceans feed. They can also cause the favourable pigmentation of several animals. The iron fertilization experiments aimed at increasing algal proliferation but their impact is still under debate. Nonetheless, algae have their harmful side as they can be toxin producers and biofoulers. Aquatic animals such as fish and crustaceans provide human beings with high-quality protein diets. Meals of aquatic animals are based partially or even entirely on algae. Marine algae can be grown as maricultures in marine environments in various forms. Also, algae can be used for fish diets in inland aquacultures. However, the types of algae vary according to the type of aquaculture. Algae can also be grown not only for their nutritional value but also for their pigments that can affect the colour and health of some aquatic animals. Recently the iron limitation in marine environments attracted the attention of scientists as the deficiency in this element caused a reduction in phytoplanktons. Iron fertilization in the ocean was performed in order to enrich some marine environments with iron, which in turn would lead to an increase of the phytoplankton. Scientists propose that this would cause mitigation of global warming as algae take in carbon dioxide, the main factor responsible for global warming, and release oxygen during photosynthesis. The number of aquatic animals is also expected to increase. However, the short and long term overall effects of those experiments are yet to be evaluated.

Toxic algae can also adversely affect aquatic animals and can cause a massive die off. The two main algal groups responsible for toxins production are cyanobacteria and dinoflagellates.

They can spread from one water body to another through ballast water or biofouling aquatic vessels such as ships and boats. This, in turn, would be harmful and even lethal for aquatic animals and would jeopardize food security. Thereby, surveillance of aquatic vessels must be performed.

On the other hand, the chapter titled "Climate Change Impact on Immune Status and Productivity of Poultry as well as the Quality of Meat and Egg Products" is presented to discuss the impacts of climate change on immune status and productivity of poultry. Also, it explains how climate change affects the quality of meant and egg products. Additionally, the chapter focuses on the key principles (nutritional or managerial practices) to alleviate the adverse impacts of heat stress.

Current poultry production systems comprise large numbers of birds that are housed together. This results in heat stress, which affects the poultry systems making them more susceptible to heat stress. Heat stress causes (i) inconvenience and high mortality rate for birds, and (ii) lower or lost production, which therefore reduces the profitability. Both production performance and feed conversion ratio are affected

by heat stress conditions, which affect the production rate. Other effects that are connected to heat stress include immunity reduction and weak immune response to vaccines that decrease the resistance of birds to many infectious diseases. In laying hens, the production is significantly decreased and does not reach to the peak a decrease in the egg quality (e.g., thin and breakable eggshell) in addition to lower egg weight with small size.

The last chapter in this section is titled "Climatic Change and Chicken Immunity". The chapter is presented to compile the current knowledge about the importance and impact of climatic change, warming the global, on chicken production, focusing on chicken immunity. Chickens have very strong built-in defenses (immunity) against diseases that are caused by overrunning of the body by various microorganisms and toxins. Under stress conditions, avian blood tolerates a change from acid-base balance to alkaline balance. There is a decline in the plasma, a reduced level of vitamin C in the adrenal cortex, a reduction in lymphocytes, and a depression of the immune response. As the temperature rises, the birds undergo many changes—increased water consumption, respiration rate, body temperature, inferior egg quality, and susceptibility to diseases.

The highly specific adaptive immune mechanisms are affected by heat stress. In more specific, heat stress deteriorates the cell-mediated immune responses. As a result of heat conditioning, biochemical and physiological mechanisms were induced to cope with heat stress; this induction may have delayed production of additional acute phase proteins to protect the cells from damage. The stress hormones—cytokine interactions are responsible for altered immune functions during heat stress. Modern-day molecular biology tools can help in understanding various cellular and molecular mechanisms involved in the production, physiological and immunological aspects of the poultry birds, which in turn can help in the development of breeds more adapted to the climate changes.

3.5 Socioeconomic Impacts

The socioeconomic impacts of climate change are covered in three chapters. The chapter titled "Climate Change, Agriculture, and Rural Communities' Vulnerability in the Nile Delta" discusses the severe impacts of climate change on agricultural production and rural communities in the Nile Delta in Egypt. However, immediate challenges, such as population growth, land fragmentation, and urban expansion on agricultural land if not timely curbed will further exacerbate future climate change impact. Agriculture in Egypt in general and in the Nile Delta in particular, is currently facing other intense challenges resulting from the rapid population growth that is exceeding 2.5% annually [13], thus augmenting agricultural land and irrigation water scarcities.

Farmers in Egypt are expected to suffer from climate change impacts, and the Nile Delta in the northern part of Egypt—comprising about 50% of the agricultural land—is identified as one of the world's three "extreme" vulnerability hotspots.

The Nile Delta is central for the production of field crops' and the provision of related agricultural employment in Egypt. However, there are present socio-economic (e.g., population growth, land fragmentation and urbanization of agricultural land) and natural resources (e.g., water and soil) challenges that negatively affect agricultural production, farmers' livelihoods, and national food security.

The chapter explores the change in agriculture in the Nile Delta governorates, in terms of field crops' agricultural land area, production, net value, and employment, stemming from socio-economic challenges, and those caused by the climate change stimuli, here, temperature increase and sea-level rise by 2030.

Population growth and land fragmentation are expected to constrain farmers' resilience to averse the negative impacts of climate change, while urbanization on agricultural land would increase the effects of climate change on the local and national levels contributing to the eruption of social tensions.

Though all Nile Delta governorates are suffering from the presence of high illiteracy and poverty rates, and the absence of strong associative structures, qualified extension information and target group specific support, some governorates are to be affected more by climate change than others.

While the chapter titled "Water Climate Food Nexus for Green Sustainability" deals with Water-Climate-Food Security (WCF) Nexus approach as an important tool to reduce future challenges due to climate hazards. Whatever applying this approach need to devote more time and efforts for developing a coordination mechanism horizontally between different sectors and vertically between many stakeholders and authorities. Implementing for such mechanisms, it could be used the natural resources with optimum manner.

Green Sustainable Development (GSD) is that meets the needs of the present without compromising the ability of future generations to meet their own needs. At the core of sustainable development is the need to consider "three pillars" together: society, the economy, and the environment. No matter the context, the basic idea remains the same—people, habitats, and economic systems are inter-related.

The interrelationship between many Sustainable Development Goals (17 SDGs) supporting the nexus approach. Among the SDGs 17 goals; Achieving SDG 13 on climate Action required a close nexus with other key SDGs on the social agenda; especially goal 1 reducing poverty, SDG 2 for food security, SDG 3 improving health, SDG5 Gender equity, SDG6 for water Access, SDG 10 for inequality and SDG 15 for land and Ecosystems, and finally SDG 17 for Partnerships.

The last chapter in this section is titled "Climate Impact on Egyptian Agriculture: An Efficiency Analysis Approach" is presented to assess the impact of average maximum temperature, humidity and solar radiation through the technical efficient governorates using panel frontier models. Climate Smart Agriculture (CSA) is an approach that deals with restructuring agricultural systems to cope with climate change through three main objectives, which are sustainability increasing productivity and incomes, mitigating GHG emissions, and adaptation and building resilience. The Intergovernmental Panel on Climate Change (IPCC) has released a special report on 2018 on the impact of global warming of 1.5 °C and GHG emission pathways.

Additionally, the report has shown that most climate models showed robust results of regional climate characteristics differences [14].

Both agriculture and climate change impact each other. Climate change affects agriculture in different ways through changing the intensity, the frequency, and occurrence of events (rainfall, heat waves, changes in pests and diseases, changes in carbon dioxide, droughts) that are not common in the location´s history. Egypt is considered one of the countries that are vulnerable to climate change impact because it is located in a region that falls between semi-arid and arid conditions, where 94.5% of Egypt total area is desert. The 5.5% of the area is populated with 95 million inhabitants that where the River Nile and the coastal area. The objective of this study is to assess the climate impact using different indicators (humidity, average maximum temperature) on cereals production and technical efficiency in five governorates (Behera, Gharbia, Kafr-Elsheikh, Dakahlia, and Sharkia) from the year 2000 to the year 2009.

The graphical analysis of the mean Vegetation Condition Index (VHI) exhibits a positive trend over time for the analyzed governorates and the Agricultural Stress Index (ASI) indicator exhibits high fluctuations for season 2 compared with season 1 considering the higher the index value the more likelihood of facing drought. The increase in the ASI was more intense for Behera, Gharbia, Sharkia, which represent the old lands and New Valley that represent the new lands. Results of the frontier analysis, production elasticity estimates indicate that, for all governorates, the cultivated area has the largest positive effect on the quantity produced. In the case of the rice model, cultivated land, labor and fertilizers are found to have statistically significant influence; lagged rice production has an adverse impact on current production because of the government policy to minimize water resources consumption. Also the results of the analysis show that the average maximum temperature and humidity are found to increase the technical inefficiency of the cereals producers.

The book ends with the conclusions and recommendations in last chapter.

Acknowledgements The editors who wrote this chapter would like to acknowledge the authors of the chapters for their efforts during the different phases of the book including their inputs in this chapter.

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