Sustainable Agriculture and Climate Changes in Egypt

Hassan R. El-Ramady, Samia M. El-Marsafawy, and Lowell N. Lewis

Abstract Egypt is one of the most populous countries in Africa. Most of Egypt 82.2 million people live near the banks of the Nile River, in an area of about 40,000 km^2, where the only arable land is found. The large areas of the Sahara Desert are sparsely inhabited. About half of Egypt's residents live in urban areas, with most people spread across the densely populated centers of greater Cairo, Alexandria and other major cities in the Nile Delta. Egypt's fertile area totals about 3.3 million ha, about one-quarter of which is land reclaimed from the desert. However, the reclaimed lands only add 7% to the total value of agricultural production. Even though only 3% of the land is arable, it is extremely productive and can be cropped two or even three times annually. Most land is cropped at least twice a year, but agricultural productivity is limited by salinity, which afflicts an estimation of 35% of cultivated land, and drainage issues. Climate change is a natural phenomenon, but humankind has drastically altered the process. Climate change has the potential to affect agriculture through changes in temperature, rainfall timing and quantity, CO_2, and solar radiation. Agriculture can both mitigate or worsen global warming. Some of the increase in CO_2 in the atmosphere comes from the decomposition of organic matter in the soil, and much of the methane emitted into the atmosphere

H.R. El-Ramady (✉)
Soil and Water Sciences Dept, Faculty of Agriculture, Kafrelsheikh Uni, 33516 Kafr El-Sheikh, Egypt
e-mail: hassanelramady@rocketmail.com; ramady2000@gmail.com; hassan.elramady@agr.kfs.edu.eg

S.M. El-Marsafawy
Soil, Water and Environment Research Institute (SEWRI), Agricultural Research Center, Giza, Egypt

L.N. Lewis
Emeritus Professor, University of California, Rambla de Catalunya 47, 08007 Barcelona, Spain

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is caused by the decomposition of organic matter in wet soils such as rice paddies. Egypt's agricultural development has been constrained by, among other factors, the need to conserve scarce natural resources, the pressures of rapid urbanization, the onslaught of the desert, and, not least important, technological limitations and restrictive economic structures.

The major conclusions are (1) due to increasing recognition of climate change, agriculture in Egypt is increasingly supporting issues of sustainable agricultural production systems, and (2) most effects of climate change on sustainable agriculture in Egypt could be changed through mitigation and adaptation.

Keywords Sustainability science • Climate changes • Sustainable agriculture • Egypt

Abbreviations

BC	Before Christ
CAPMAS	Central Agency for Public Mobilization and Statistics
GDP	Gross Domestic Production
GCOS	Global Climate Observing System
GHGE	Greenhouse Gases Emissions
IPCC	Intergovernmental Panel on Climate Change
EEAA	Egyptian Environmental Affairs Agency
INC	Initial National Communication
MDGs	Millennium Development Goals
MSL	Mean Sea Level
NGOs	Non-Governmental Organizations
SNC	Second National Communication
SRU	Strategic Research Unit
UNDP	United Nations Development Programme
UNESCO	United Nations Educational Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization

1 Introduction

Egypt lies on the northeastern side of Africa, bordered on its northern coast by the Mediterranean Sea and on its eastern coast by the Red Sea. It comprises an area of about 1 million km^2, made up as follows: Nile valley and delta about 4% of the total; Eastern desert area about 22%; Western desert area about 68%; and the Sinai Peninsula area about 6%. The share of Nile water in Egypt is 55.5 billion m^3 year^{-1}, representing 76.7% of the country's available water resources; desalinated seawater comprises only 0.08%. Total groundwater plus treated groundwater is 20.65 billion m^3 $year^{-1}$ (28% of available water resources), but it cannot be added to Egypt's share of water as it is a reused source (CAPMAS 2009).

Awareness and concern for problems related to environmental quality are growing at a steady pace: climate change, biodiversity, soil fertility decay and above all food quality and pollution are everyday subjects for debates and discussions. The complexity of the problems and the uncertainty about many basic data quite often make discussions inconclusive; even indications issued by scientific authorities are sometimes misleading, and the problems are exacerbated by the frequent influence of ideological positions (Wu and Sardo 2010).

Agriculture production has to increase by 70% within 2050 in order to keep pace with population growth and changing diets. However, this production increase will have to be achieved in a way that preserves the environment and reduces the vulnerability of agriculture to climate change. Agriculture will furthermore need to minimize the emissions of greenhouse gases, pesticides and plant nutrients like nitrogen and phosphorous to the environment (Aune 2012).

The main role of agriculture is to produce food for a growing population. However, this production has to be achieved in an environmentally friendly way that minimizes the external effects of agriculture related to the emission of green house gases, the release of nitrogen and phosphorous to the environment and the use and accumulation of harmful pesticides in nature. Agriculture will also need to adapt to climate change including more extreme weather events. In principle, there are three pathways for agricultural development: conventional agriculture, organic agriculture and conservation agriculture. These pathways have different approaches for addressing the above issues (Aune 2012).

Despite its prediction 100 years ago by scientists studying CO_2, manmade climate change has been officially recognized only in 2007 by the Nobel Prize Committee. Climate changes since the industrial revolution have already deeply impacted ecosystems. The lesson from the climate change story is that humans do not learn from scientists until it really hurts. Furthermore, all society issues cannot be solved anymore using the old, painkiller approach because all issues are now huge, linked, global and fast-developing. In that respect, actual society structures are probably outdated. Here, agronomists are the most advanced scientists to solve society issues because they master the study of complex systems, from the molecule to the global scale. Now, more than ever, agriculture is a central point to which all society issues are bound; indeed, humans eat food (Lichtfouse 2009).

More than 100 years ago, the Nobel Prize winner Svante Arrhenius (1859–1927) estimated that a doubling of atmospheric CO_2 concentration would cause a temperature rise of about +5–6°C (Arrhenius 1896). Remarkably, his crude estimate is higher but not largely different from the +2.0–4.5°C rise now estimated by the Intergovernmental Panel on Climate Change (IPCC 2007). Combining his calculations with existing work suggesting that the burning of fossil fuels could significantly alter the concentration of carbon dioxide in the atmosphere (Hoegbom 1894), Arrhenius later became the first person to predict the possibility of man-made global warming (Arrhenius 1908; Weart 2008; Lichtfouse 2009).

2 Sustainable Agriculture in Egypt

Some researchers define sustainable agriculture primarily as a technical process. Altieri (1989) defined sustainable agriculture as a system, which should aim to maintain production in the long run without degrading the resources base, by using low-input technologies that improve soil fertility, by maximizing recycling, enhancing biological pest control, diversifying production, and so on. The technological and to a lesser extent economic dimensions of sustainable agriculture have tended to be privileged while the social dimension has been neglected. As a result sustainable agricultural has suffered from limited adoption (Karami and Keshavarz 2010).

A sustainable farming system is recognized as a system that maintains the resource base upon which it depends, relies on minimum of synthetic inputs, manages pests and diseases through internal regulating processes, and can recover from the human disturbance caused by agricultural practices, i.e., cultivation and harvest (Altieri 1995). Sustainable agriculture is farming systems that are maintaining their productivity and benefit to society indefinitely (Lichtfouse et al. 2009).

Despite the diversity in conceptualizing sustainable agriculture, there is a consensus on three basic features of sustainable agriculture: (1) maintenance of environmental quality, (2) stable plant and animal productivity, and (3) social acceptability. Consistent with this, Yunlong and Smith (1994) have also suggested that agricultural sustainability should be assessed from ecological soundness, social acceptability, and economic viability perspectives. "Ecological soundness" refers to the preservation and improvement of the natural environment, "economic viability" to maintenance of yields and productivity of crops and livestock, and "social acceptability" to self-reliance, equality, and improved quality of life (Karami and Keshavarz 2010).

In conclusion, sustainable agriculture is defined simply as farming systems that are maintaining their productivity and benefit to society indefinitely. This sustainable agriculture has three basic features, e. g. maintenance of environmental quality, stable plant and animal productivity, and social acceptability.

2.1 Definition of Agriculture

What is agriculture? It is the first point to clarify and there is of course general agreement about the sorts of things, people, plants, and animals that can be called agricultural, but this is not good enough if we are seriously interested in topics such as the role of science in agriculture, the role and importance of agriculture in the world, and how agricultural efficiency can be improved (Speeding 1988). Not many attempts have been made to be more precise and it is quite difficult to arrive at a definition that is both useful and specific. One of the useful definitions is phrased by Speeding (1988, 1996) as follows: "agriculture is an activity of Man, carried out primarily to produce food, fiber and fuel, as well as many other materials by the deliberate and controlled use of mainly terrestrial plants and animals" (Karami and Keshavarz 2010).

Therefore, agriculture also called farming or husbandry is the cultivation of animals, plants, fungi, and other life forms for food, fiber, biofuel and other products used to sustain life. Agriculture was the key development in the rise of sedentary human civilization, whereby farming of domesticated species created food surpluses that nurtured the development of civilization. The study of agriculture is known as agricultural science.

2.2 Sustainability Science

Sustainability is the core element of government policies, university research projects, and extension organizations worldwide. Yet, the results of several decades of attempt to achieve sustainable agriculture have not been satisfactory. Despite some improvement conventional agriculture is still the dominant paradigm. Sustainability, climate change, and replacing fossil fuels with renewable energy are relatively new challenges for agriculture. Sustainability is not only a challenge in itself, but also a new worldview, a paradigm, which has changed our understanding of agriculture. Sustainable agriculture as a concept has emerged to address the challenges that are facing modern agriculture. Across all literatures, two broad paradigms of sustainability are identifiable: one supporting a systems-level reconstruction of agricultural practice to enhance biological activity, and the other adopting a technological fix, in which new technologies inserted into existing systems can improve sustainability outcomes (Karami and Keshavarz 2010).

It could be selected from some of the major ideas of sustainability science that contributed to the development of sustainability science from a much larger set, beginning first with Alexander von Humboldt's dream of understanding the unity of nature. This was followed by George Perkins Marsh's vision of nature as modified by human action. Then much later, the International Union for the Conservation of Nature (IUCN) linked nature and human development, which led to the World Commission on Environment and Development, and culminated in the US National Academy of Science (NAS) report of *Our Common Journey* and the call for a sustainability science (Kates 2012).

Sustainability science could be defined as follows "*an emerging field of (transdisciplinary) research dealing with the interactions between natural and social systems … how those interactions affect the challenge of sustainability: meeting the needs of present and future generations while substantially reducing poverty and conserving the planet's life support systems*" (Weinstein and Turner 2012). Balancing human needs with the ability of ecosystems to provide the goods and services that we all depend on is a fundamental formula for the global sustainability transition (Fig. 1).

Equilibrium can be attained either by increasing these goods and services or by reducing our consumption of them, or in today's world, both! Any solution to the emerging conflicts arising on the path to long-term sustainability will, in part, require the integration of the biophysical and social sciences into a new transdisciplinary science that we refer to as "*sustainability science*".

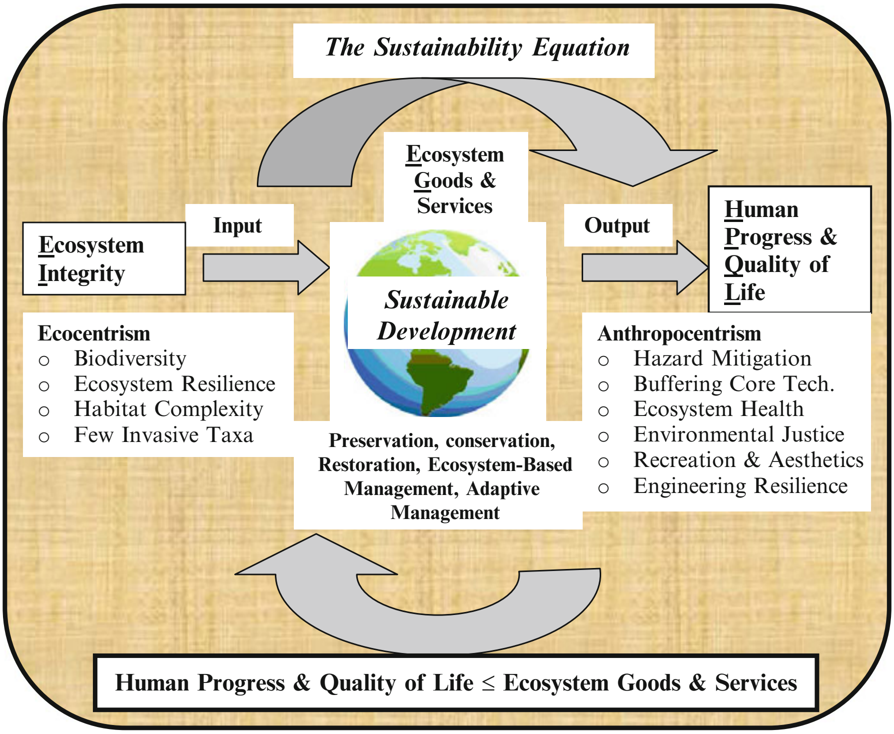


Fig. 1 The "Sustainability Equation" balancing human needs with ecosystem integrity (Adapted from Weinstein and Turner 2012). Note the increase of the inputs (ecosystem integrity) through ecosystem goods and service follows by increasing the outputs (human progress and quality of life and finally sustain the global development)

Therefore, sustainability science has emerged in the twenty-first century as a new academic discipline. This new field of science was officially introduced with a '*Birth Statement*' at the World Congress 'Challenges of a Changing Earth 2001' in Amsterdam. The name of this scientific field reflects a desire to give the generalities and broad-based approach of "sustainability" a stronger analytic and scientific underpinning. Sustainability science, like sustainability itself, derives some impetus from the concepts of sustainable development and environmental science. Sustainability science provides a critical framework for sustainability while sustainability measurement provides the evidence-based quantitative data needed to guide sustainability governance.

2.3 *Sustainable Development*

Sustainable development was defined as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. If needs are to be met on a sustainable basis, the Earth's natural resources must be well managed and enhanced. Also, it is defined as a development strategy that manages all assets, natural resources and human resources as well as financial and physical assets, for increasing long-term wealth and well-being. Development is a value-laden word implying change that is desirable. It may be considered a *vector* of desirable society objectives, the elements of which might include (Pearce et al. 1990): increase in real income per capita, access to resources, and a "fairer" distribution of income. Sustainable development has been described as a path toward the twin goals of social justice and environmental protection. It rejects policies and practices that support current living standards by depleting the productive base, including natural resources and that leaves future generations with poorer prospects and greater risks than our own. In its broadest sense, the strategy for sustainable development aims to promote harmony among human beings and between humanity and nature. Bases for sustainable development include: (1) reliable scientific information, (2) consensus on ethical principles, (3) hope for the future, and (4) consideration of personal interest and incentives. "*It could be managed as our resources only if we know what we have and what we are doing to them. We need to agree on the reasons for preserving and distributing resources. We also need assurance that progress is possible and that we or our descendents will benefit from that progress*" (Cunningham and Saigo 1992) Also, Kassas (2004) stated that sustainable development could be realized through three main bases: (1) social equality, (2) economic efficiency and (3) environmental conservation. He added that it is the responsibility of the governmental institutions, in collaboration with the international and regional organizations, to implement programs aiming at the conservation of the natural resources, e.g. the biodiversity, and to protect them against deterioration (Zahran and Willis 2009).

In conclusion, sustainable development (SD) is a pattern of economic growth in which resource use aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for generations to come. The term "*sustainable development*" was used by the Brundtland Commission which coined what has become the most often-quoted definition of sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs." Alternatively, sustainability educator Michael Needham referred to sustainable development "*as the ability to meet the needs of the present while contributing to the future generations' needs*" (Needham 2011). There is an additional focus on the present generations "*responsibility to improve the future generations*" life by restoring the previous ecosystem damage and resisting to contribute to further ecosystem damage.

2.4 Sustainable Agriculture in Ancient Egypt

Ancient Egypt was an ancient civilization of Northeastern Africa, concentrated along the lower reaches of the Nile River in what is now the modern country of Egypt. Egyptian civilization coalesced around 3150 BC (according to conventional

Egyptian chronology) with the political unification of Upper and Lower Egypt under the first pharaoh. The search for an ancient society that approached a sustainable balance with the environment must inevitably lead the environmental historian to Egypt. The Egyptians were in charge of their own government and able to set their own environmental policies from before 3000 BC to after 1000 BC. No other ancient civilization lasted so long, while maintaining a stable pattern in its economy, government, religion, and ecological viewpoints and techniques. Many historians of Egypt remark upon the stability of Egyptian culture in a pejorative tone, attributing a lack of change to traditionalism and absence of creative thought, as if stability were only stagnation. But it will be suggested here that the stability of Egyptian civilization was the result of the sustainability of Egypt's ecological relationships (Hughes 1992).

The many achievements of the ancient Egyptians include the quarrying, surveying and construction techniques that facilitated the building of monumental pyramids, temples, and obelisks; a system of mathematics, a practical and effective system of medicine, irrigation systems and agricultural production techniques, the first known ships, Egyptian faience and glass technology, new forms of literature, and the earliest known peace treaty with Hittites. The sustainability of Egyptian agriculture was made possible first of all by the annual flood of the Nile and the deposition of fertile alluvial soil containing phosphorus and other minerals and traces of organic debris brought down from the mountains and swamps of lands further south. The Greek historian Herodotus, observing that the very soil of Egypt had been formed by river sediment, pronounced Egypt the "gift of the Nile". The Egyptians were aware of this, for as an early inscription witnesses, the Nile supplies all the people with nourishment and food. Second, they had a stable climate without freezing or storms, and although there was little rain, the river supplied the water needed. Their environment encouraged them to think of processes of nature as operating in predictable cycles. The Nile flooded its banks at the same time every year, bringing moisture and new soil to the fields, and then subsided. The only fertile land was what the river watered, both in the long, narrow cultivated valley floor of Upper Egypt and in the broad, flat, fruitful Delta of Lower Egypt (Fig. 2; Hughes 1992).

Egypt left a lasting legacy. Its art and architecture were widely copied, and its antiquities carried off to far corners of the world. Its monumental ruins have inspired the imaginations of travellers and writers for centuries. A new-found respect for antiquities and excavations in the early modern period led to the scientific investigation of Egyptian civilization and a greater appreciation of its cultural legacy. In spite of Egypt's remarkable success in maintaining sustainable agriculture, some environmental problems appeared. One, ironically, was a result of the success of the Egyptians in producing the ancient world's most reliable food supply. The most dependable system will fail with over-population. When population increased to near a level that could be supported in a year of good harvest, an abnormally low harvest would bring famine. Egypt suffered because fat years alternated with lean ones, and population had its peaks and valleys as a result. Governmental officials tried to even out fluctuations of supply and demand by storing surplus in good years and distributing it when the harvest failed. The story of Joseph's interpretation of

Sheep, goats, cattle, pigs and geese were raised from earliest times and supplied milk, wool, meat, eggs, leather, skins, horn and fat

Wall painting from 1200 BC showing an Ancient Egyptian ploughing his field

A tomb relief depicts workers plowing the fields, harvesting the crops, and threshing the grain under the direction of an overseer

Sennedjem plows his fields with a pair of oxen, used as beasts of burden and a source of food.

Fig. 2 Some agricultural practices photos from Ancient Egypt from different websites (www.ancientegyptmagazine.com, www.wekipedia.com and www.experience-ancient-egypt.com/images/ancient-egyptian-farming.jpg/ 28.6.2012)

Pharaoh's dream, and his advice to build granaries to prepare for hard times, is a reflection of the actual situation in Egypt. The store chambers of the Ramesseum, built at the order of Ramses II, could easily have held 590,000 cu. ft. of grain, enough to support 3,400 families for a year. In difficult periods, prices fluctuated widely. In the 55 years between the reigns of Ramses III and Ramses VII, for example, emmer wheat rose from 8 to 24 times base price. At times, famine relief had to be distributed over wide territories. Even so, Egypt remained the breadbasket of the ancient world, exporting wheat and barley with few interruptions (Hughes 1992).

Therefore, a combination of favorable geographical features contributed to the success of ancient Egyptian culture, the most important of which was the rich fertile soil resulting from annual inundations of the Nile River. The ancient Egyptians were thus able to produce an abundance of food, allowing the population to devote more time and resources to cultural, technological, and artistic pursuits. Land management was crucial in ancient Egypt because taxes were assessed based on the amount of land a person owned. Farming in Egypt was dependent on the cycle of the Nile River. The Egyptians recognized three seasons: *Akhet* (flooding), *Peret* (planting), and *Shemu* (harvesting). The flooding season lasted from June to September, depositing on the river's banks a layer of mineral-rich silt ideal for growing crops. After the floodwaters had receded, the growing season lasted from October to February.

2.5 Sustainable Agriculture in Modern Egypt

The total area of Egypt is about 1 million km^2, most of which is under arid and hyper-arid climatic conditions, and of which a small portion representing only 3% is agriculturally productive. The six main agro-ecological zones in Egypt are the Nile Valley including the fertile alluvial land of Middle and Upper Egypt, where the main source of irrigation water is the Nile River. Agriculture production of Egypt is mainly concentrated in this zone in addition to the Delta as follows:

1. The Nile Delta region, where the main source of irrigation water is the Nile River as well. Together with the Nile Valley, the agriculture production in this zone consists of about 6.6 million acres. Most of the soil in both areas is recent Nile alluvium.
2. The reclaimed desert areas in the fringes of the Nile Valley, where the only source of irrigation is the ground water.
3. North Coastal zone: including the coastal area starting from North-Western coast moving eastwards to North coastal area of Sinai Peninsula, where there are no reliable figures are available neither on ground water quantity or usage.
4. The Inland Sinai and the Eastern Desert, where the main source for irrigation is the ground water.
5. The Western Desert including oases and southern remote areas, where the groundwater is mainly extracted from the Nubian Sandstone and carbonate aquifers.

Although the Nile River streams through the Egyptian land, water is regarded as a scarce natural resource, due to the rapidly growing population in Egypt, the latter's limited quota of the Nile Water and the wide desert lands where the main drinking and irrigation water resource is the underground water. Furthermore, the Egyptian land suffers from different variations of degradation around the country, depending on the region and the inhabitants (Afifi 2009).

According to report of Handoussa (2010) about *situation analysis: key development challenges facing Egypt*, it could be concluded the following topics about the sustainable agriculture in modern Egypt:

1. *Issues of Sustainable Agricultural Development*:

The link between environmental and sustainable agricultural and rural development, enhancing food security, and reducing poverty is a central issue for achieving economic and social development in Egypt. The contribution of the agriculture sector in Egypt exceeds 13% of GDP and over 30% of employment opportunities. Meanwhile, about 57% of the total population in Egypt lives in rural areas, where poverty prevails. As such, enhancing sustainable agricultural and rural development as a means to reduce poverty and food insecurity within the expected climate changes is a prerequisite for sustainable social and economic development and hence should be considered as a social and political priority for Egypt. In Egypt, agriculture is recognized as a way of life and crucial for socio-economic development, but if received the due attention, also as an engine for growth.

2. *Rural Poverty and Food Security*:
There is a strong correlation between economic growth and the reduction of hunger and poverty as well as a strong link between poverty and food insecurity. Most of the poor are either under-nourished or food insecure. Lower income households spend a large share of their income to purchase food. They are particularly vulnerable to variations in food prices and food scarcity. Nearly 70% of the poor or food-insecure live in rural areas and a large share of these people depend very much on agriculture for their food supplies (produced locally) and for generating incomes. Economic diversification starts at the farm household, and agricultural and non-agricultural development reinforce each other. Pro-poor policies and strategies must emphasize food security, access to land and water, agriculture and rural development. Large numbers of rural households depend on agriculture and farming (production) but it is rarely the main income contributor. Farm incomes account on average for about 25–40% of total rural income, agricultural related off farm incomes account for an additional 20–35%, and non-farm revenues and wages account for about 40% of rural household incomes.

3. *Improving Irrigation Efficiency*:
Pollution of waterways and groundwater due to domestic and industrial wastewater and solid waste disposal is another problem that reduces the availability of appropriate quality water for use. The competition between development sectors on water and between users of the same sector is growing and is expected to create water conflicts. The number of irrigation water complaints due to water shortages is known to have increased recently. Due to the limited water resources, the irrigation water shortages are exacerbated by illegal water intakes and violations in cultivating more than the allowable areas of high water consumptive crops, such as rice. Treated wastewater is expected to be the renewable water resource for agriculture expansion in the future, if no additional share of Nile waters is mobilized, and the existing Egyptian code for treated wastewater reuse in agriculture will need to be properly implemented.

4. *Depletable Energy Sources*:
Hydrocarbons such as oil and gas represent over 90% of Egypt's energy resources, a situation that is expected to continue for at least the next 20 years, with natural gas slowly replacing crude oil. Egypt's reserves have been increasing at an average of 5% per year during the last 5 years and natural gas reserves accounted for most of this growth, while crude oil and condensate reserves remained relatively constant. Domestic consumption however, has been rapidly increasing as a result of ongoing economic growth. Recent and forecasted consumption patterns signal an alarm to those responsible for the country's future economic development and energy security. Energy efficiency and renewable energy resources are expected to play a critical role in facing this challenge.

5. *Climate Changes*:
The energy sector is the main source of greenhouse gas emissions with 92% of the country's energy demand met by using fossil fuels. It is worth noting that Egypt's greenhouse gas emissions are relatively limited (0.7% of global greenhouse gas), but they grew to 193 million tons of CO_2 equivalent in 2000 from 116 million tons of CO_2 equivalent in 1990 (Egypt's initial national communication/second national communication). However, Egypt is subject to potential impacts of climate change, including sea level rise, inundation of the low lying lands in the Nile Delta that could reach 10–12% of the total area, impacts on water resources and agricultural productivity and associated social and economic effects. Moreover, 57% of the Egyptian population lives in rural areas, considered more vulnerable to climate change, with an expected shortage of basic food items. The increased concentration of greenhouse gases in the atmosphere are causing disruptions in climate systems and the broad impacts can be divided into two main groups (Table 1).

6. *Impact of Climate Change on Health*:
Climate change is also closely linked to the health sector, with expected increases in morbidity and deaths due to non communicable diseases, disasters, and vector-borne diseases. There are some efforts to reduce the impacts of climate change in some sectors. Currently, however, there are no efforts to cope with the different direct and indirect impacts of climate change on health. Moreover, building institutional capacity must be pursued vigorously in order to deal adequately with the necessary adaptation measures, providing the country with both a strategy and a trained capacity to implement the required measures.

7. *Egypt 2050 – The Need for a National Urban Development Plan*:
If Egypt's continued high rate of natural population increase is not reduced it could result in a population of 140 million inhabitants by 2050. This challenge calls for the need to develop a new vision for Egypt that mainly aims to:

- Achieve balanced urban development by focusing on the development of small and medium-sized cities, especially in Upper Egypt, to eradicate poverty and improve the socio-economic status within those deprived areas;
- Redefine the roles of existing poles such as Cairo, Alexandria, Port Said and others in an overall policy framework that focuses on building on the regional competitiveness potentials of each pole and how it can be integrated within the overall new urban development policy;
- Increase the inhabited area from 5.5% to 15% of the total area during the next four decades through establishing new urban centers that are well connected with efficient road networks and national public transportation systems. Each center would work as a catalyst for the development of its surroundings and attracting a defined number of the increasing population with a clear economic basis and activities;

Table 1 Egypt at a glance from 1988 to 2008 through some indicators: the key economic ratios and long-term trends, structure of economy (average annual growth and gross domestic production), trade and balance of payment (Adapted from UNDP 2011)

Item	1988	1998	2007	2008
Key Economic Ratios and Long-Term Trends				
GDP (US$ billions)	35.0	84.8	130.5	162.3
GDP (average annul growth)	4.1	4.6	7.1	7.2
GDP per capita	2.0	2.7	5.1	5.2
Gross capital formation/GDP	34.9	21.5	20.9	22.5
Exports of goods and services/GDP	17.3	16.2	30.3	33.2
Current account balance/GDP	–1.6	–2.9	1.7	0.5
Structure of Economy (% of GDP)				
Agriculture	19.0	17.1	14.1	13.2
Industry	28.8	30.9	36.3	37.5
Services	52.2	52.0	49.6	49.2
Imports of goods and services	35.2	25.7	34.8	38.8
Structure of Economy (average annual growth)				
Agriculture	2.9	3.4	3.7	3.3
Industry	6.0	4.9	7.9	10.3
Services	3.0	5.1	7.4	8.6
Imports of goods and services	2.8	11.4	28.8	26.3
Trade (US$ millions)				
Total exports (free on board, fob)	3,274	5,128	22,018	29,356
Cotton	480	1,728	110	194
Other agriculture	354	103	10,223	14,628
Manufactures	961	1,885	7,519	10,932
Total imports (cost, insurance, freight, cif)	8,858	16,899	38,308	52,771
Food	1,254	3,193	2,671	3,927
Fuel and energy	2,148	2,188	4,336	10,001
Capital goods	2,188	4,801	9,845	11,871
Balance of Payments (US$ millions)				
Exports of goods and services	7,225	13,502	39,428	53,277
Imports of goods and services	11,689	21,795	45,398	63,086
Resource balance	–4,465	–8,292	–5,969	–9,809
Net income	–161	1,213	1,177	1,360
Current account balance	–545	–2,479	2,269	888

GDP gross domestic production, *US$* United States dollar

- Deal with the potential link between climate change (including SLR, water scarcity and desertification) and human mobility (including displacement) in Egypt. Given its potential magnitude, environmentally induced migration could impact adversely upon various human development issues (for example, rapid urbanization and associated environmental health issues) and undermine the important progress outlined in this report;
- Support the decentralization of management, planning and implementation.

In conclusion, agriculture production of Egypt is mainly concentrated in the Nile Valley zone in addition to the Delta. About the sustainable agriculture in modern Egypt, it could be concluded that the key sustainable development challenges facing Egypt include the following topics: climate change, issues of sustainable agricultural development, impact of climate change on health, rural poverty and food security, the need for a national urban development plan, depletable energy sources and improving irrigation efficiency.

3 The Climate of Egypt

The land of Egypt occupies the northeastern part of the African continent. It is roughly quadrangular, extending about 1,073 km from north to south and about 1,229 km from east to west. Thus, the total area of Egypt is a little more than one million square kilometers (1,019 600 km^2) occupying nearly 3% of the total area of Africa (Abu Al-Izz 1971). Egypt is bordered on the north by the Mediterranean Sea, on the south by the Republic of Sudan, on the west by the Republic of Libya and on the east by the Gulf of Aqaba and the Red Sea.

Egypt extends over about 10° of latitude, being bounded by Lat. 22 °N and 32 °N, i.e. it lies mostly within the temperate zone, less than a quarter being south of the Tropic of Cancer. The whole country forms part of the great desert belt that stretches from the Atlantic across the whole of North Africa through Arabia. Egypt is characterized by a hot and almost rainless climate. The average annual rainfall over the whole country is only about 10 mm. Even along the narrow northern strip of the Mediterranean coastal land where most of the rain occurs, the average annual rainfall is usually less than 200 mm and the amount decreases very rapidly inland (southwards). The scanty rainfall accounts for the fact that the greater part of Egypt is barren and desolate desert. Only through the River Nile is a regular and voluminous supply of water secured, coming from the highlands hundreds of kilometres to the south. This is channeled by artificial canals over the narrow strip of alluvial land on both sides of the river, the Fayoum Depression and the delta expanse. These tracts of fertile land, covering less than 3% of the total area of Egypt, support a dense population (Zahran and Willis 2009).

According to Said (1962), the average density of population in the agricultural lands of Egypt is more than 600 persons km^2, whereas in the vast desert areas, which represent more than 97% of the total area, there is only one inhabitant/7 km^2. The River Nile, therefore, is a salient geographical feature that has shaped not only the physical tracts of Egypt but also its history and the nature of its human settlements. Herodotus (484–425 BC) states that "*Egypt is the Gift of the Nile*". This is very true as the Nile gave Egypt, out of all regions of the great North African Sahara, a fertility that made possible not only the development of the famed ancient agricultural civilization, but also the growth of this civilization in peace and stability (Zahran and Willis 2009).

3.1 Climate and Climate Changes

Climate refers to the characteristic conditions of the earth's lower surface atmosphere at a specific location; weather refers to the day-to-day fluctuations in these conditions at the same location. The variables that are commonly used by meteorologists to measure daily weather phenomena are air temperature, precipitation e.g., rain, sleet, snow and hail, atmospheric pressure and humidity, wind, and sunshine and cloud cover. There is no internationally agreed definition of the term "*climate change*". Climate changes can refer to: (1) long-term changes in average weather conditions (*World Meteorological Organization usage*); (2) all changes in the climate system, including the drivers of change, the changes themselves and their effects (*Global Climate Observing System usage*); or (3) only human-induced changes in the climate system (*United Nations Framework Convention on Climate Change usage*). Climate change as referred to in the observational record of climate occurs because of internal changes within the climate system or in the interaction among its components, or because of changes in external forcing, either for natural reasons or because of human activities. It is generally not possible to make clear attributions between these causes. Projections of future climate change reported by IPCC generally consider the influence on climate of only anthropogenic increases in greenhouse gases and other human related factors (*IPCC usage*) (FAO 2008).

According to the IPCC (2008), climate change is any "*change in climate over time whether due to natural variability or as a result of human activity*". It is general consensus among IPCC researchers that increases in atmospheric concentrations of greenhouse gasses (mainly CO_2, CH_4, N_2O and O_3) since pre-industrial times have led to a warming of the surface of the earth. During the last 250 years, the atmospheric concentrations of CO_2, CH_4 and N_2O have increased by 30%, 145% and 15%, respectively. The emissions are mainly due to the use of fossil fuels, but changes of land use as well as agriculture are also major sources of emissions (Raberg 2008).

Therefore, climate change is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average weather conditions, or in the distribution of weather around the average conditions i.e., more or fewer extreme weather events. Climate change is caused by factors that include oceanic processes such as oceanic circulation, variations in solar radiation received by Earth, plate tectonics and volcanic eruptions, and human-induced alterations of the natural world; these latter effects are currently causing global warming, and '*climate change*' is often used to describe human-specific impacts.

3.2 Why the Interest in Global Climate Change?

The world population is projected to increase from about seven billion in 2011 to 9.2 billion in 2050. The current rate of increase is about six million per month, with almost all growth occurring in developing countries where natural resources are already under great stress. The Green Revolution technology led to the doubling of food production between 1950 and 2010, with only a 10% increase in the area under production (FAO 2010). However, meeting the food demand of the growing population, rising standards of living, and changes in diet preferences will necessitate an additional 70% increase in production between 2010 and 2050 (Burney et al. 2010). Grain yields of wheat (Semenov 2009) and rice (Wassmann et al. 2009) are sensitive to high temperatures (Lal and Stewart 2012).

Climate changes caused by the progressive anthropogenic emissions of greenhouse gases is already affecting natural and human systems and sectors throughout the world and the changes to date may be only inklings of profound changes to come. Some contend that action on climate change should be delayed because of the uncertainties surrounding the exact nature, extent, and rate of the portending changes. Others believe that responding to climate change is now necessary precisely because of the uncertainties. In any case, the prospect of significant changes in agroecosystems requires us to anticipate the potential impacts of climate change, to study how farming regions and systems can adjust to those that are unavoidable, and to determine how they can mitigate climate change so as to reduce its ultimate effects (Hillel and Rosenzweig 2011).

From previous, it could be concluded that climate changes in different regions of the world showed that it is likely to vary a great deal from place to place. For instance, in some regions precipitation will increase, in other regions it will decrease. Not only is there a large amount of variability in the character of the likely change, there is also variability in the sensitivity of different systems to climate change. Different ecosystems, for instance, will respond very differently to changes in temperature or precipitation. There will be a few impacts of the likely climate change that will be positive so far as humans are concerned. For instance, in parts of Siberia, Scandinavia or northern Canada increased temperature will tend to lengthen the growing season with the possibility in these regions of growing a greater variety of crops. Also, in winter there will be lower mortality and heating requirements. Further, in some places, increased carbon dioxide will aid the growth of some types of plants leading to increased crop yields. However, because, over centuries, human communities have adapted their lives and activities to the present climate, most changes in climate will tend to produce an adverse impact. If the changes occur rapidly, quick and possibly costly adaptation to a new climate will be required by the affected community. An alternative might be for the affected community to migrate to a region where less adaptation would be needed – a solution that has become increasingly difficult or, in some cases, impossible in the modern crowded world.

3.3 Effects of Climate Change on Soil and Water Resources

Soil water balance has response to climate change and evaluation of soil water change is one of the most important items of climate change impact assessment. It is well documented also that a changing climate will affect soil and water resources

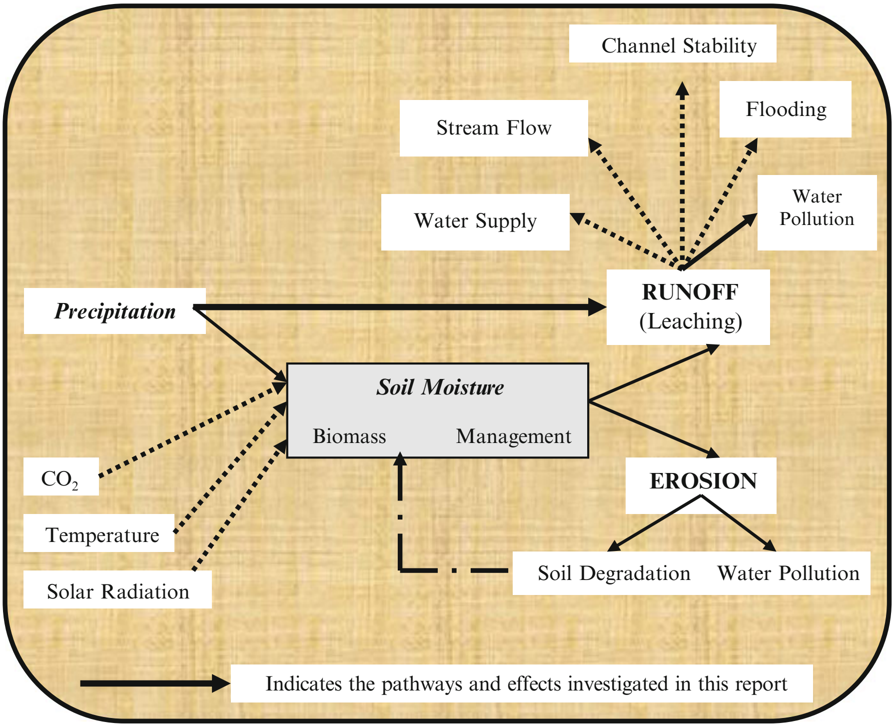


Fig. 3 Effects of climate change on soil and water resources (Adapted from SWCS 2003). Erosion and runoff are among the most important factors influencing agriculture's effects on soil and water resources, precipitation would be a dominant factor affecting conservation outcomes and that soil erosion and runoff would be particularly sensitive to changes in precipitation

on agricultural land in many ways. Will the effect of climate change on soil and water resources on agricultural land be large enough to warrant changes in world conservation policy or practice? Climate change will affect soil and water conservation through multiple pathways because many climatic variables have important effects on conservation outcomes. Those variables include precipitation, temperature, wind, solar radiation, and atmospheric carbon dioxide, among others. Change in any single variable also is complex (Fig. 3). A change in temperature, for example, will affect conservation differently if that change primarily affects minimum, maximum, or mean temperature. A change in a climatic variable also may differ seasonally or geographically. The interaction between and among climatic variables and conservation outcomes is dynamic and often nonlinear. Climatic variables interact to magnify or dampen conservation effects. Likewise, conservation effects feed back into the system and modify the influence of climatic variables. Those interactions could have profound effects on soil, water, and related natural resources. Water budgets, stream flow, and frequency and severity of floods and droughts may be altered. Biotic communities, plant growth and development, and land use patterns may shift. Those changes, in turn, may have important implications for soil, water, and air quality, as well as fish and wildlife habitat.

As the main constituent of terrestrial ecosystem, the functions and processes of soil changes in response to global climate change. Soil water reserve is one of the main sources of water that can be utilized by vegetation. The potential change of soil water induced by climate change may cause great change to ecological environment and agricultural production. Globally, climate change affects average temperatures and temperature extremes; timing and geographical patterns of precipitation; snowmelt, runoff, evaporation, and soil moisture; the frequency of disturbances such as drought, insect and disease outbreaks, severe storms and forest fires; atmospheric composition and air quality; and patterns of human settlement and land use change. Ecosystems and their services (land and water resources, agriculture, biodiversity) experience a wide range of stresses, including pests and pathogens, invasive species, air pollution, extreme events, wildfires and floods. Climate change can cause or exacerbate direct stress through high temperatures, reduced water availability, and altered frequency of extreme events and severe storms. Understanding climate impacts on each of these sectors requires monitoring many aspects of climate and a wide range of biological and physical responses.

Therefore, it could be concluded that a changing climate has effects on soil and water resources in many ways. That means, climate change will affect soil and water conservation through multiple pathways because many climatic variables have important effects on conservation outcomes. Those variables include precipitation, temperature, wind, solar radiation, and atmospheric carbon dioxide, among others.

3.4 Climate Change: A Blessing or a Curse for Agriculture?

Global climate change is a change in the long-term weather patterns that characterize the regions of the world. Scientists state unequivocally that the earth is warming. Natural climate variability alone cannot explain this trend. Human activities, especially the burning of coal and oil, have warmed the earth by dramatically increasing the concentrations of heat-trapping gases in the atmosphere. The more of these gases humans put into the atmosphere, the more the earth will warm in the decades and centuries ahead. The impacts of warming can already be observed in many places, from rising sea levels to melting snow and ice to changing weather patterns. Climate change is already affecting ecosystems, freshwater supplies, and human health. Although climate change cannot be avoided entirely, the most severe impacts of climate change can be avoided by substantially reducing the amount of heat-trapping gases released into the atmosphere. However, the time available for beginning serious action to avoid severe global consequences is growing short. Global Warming or climate change is a topic that increasingly occupies the attention of the world (Table 2). Is it really happening? If so, how much of it is due to human activities? How far will it be possible to adapt to changes of climate? What action to combat it can or should we take? How much will it cost? Or is it already too late for useful action? Why carbon dioxide is both a blessing and a curse? Is *climate change: a blessing or a curse for agriculture*?

Table 2 The impacts of climate change through both of the biophysical and socio-economical effects. These different impacts include different agricultural issues from biophysical and socio-economical point of view (Adapted from FAO 2007)

Biophysical effects	Socio-economical effects
Physiological effects on crops, pasture, forests and livestock (quantity, quality);	Decline in yields and production (exacerbating food insecurity);
Changes in land, soil and water resources (quantity, quality);	Reduced marginal GDP from agriculture;
Increased weed and pest challenges;	Fluctuations in world market prices;
Shifts in spatial and temporal distribution of impacts;	Changes in geographical distribution of trade regimes;
Sea level rise, changes to ocean salinity; and	Increased number of people at risk of hunger and food insecurity; and
Sea temperature rise causing fish to inhabit different geographical ranges	Migration and civil unrest

GDP gross domestic production

Carbon dioxide might be a greenhouse gas, but it's not necessarily bad for the planet. Without it, there'd be no plant life and no human life as we know it. It's only toxic in high concentrations. And now the most important question is the climate changing? This question could be answered as follows: It seems certain that the world will be even more crowded and more connected. Will the increasing scale of human activities affect the environment? In particular, will the world be warmer? How is its climate likely to change?

Variations in day-to-day weather are occurring all the time; they are very much part of our lives. The climate of a region is its average weather over a period that may be a few months, a season or a few years. Variations in climate are also very familiar to us. We describe summers as wet or dry, winters as mild, cold or stormy. In many parts of the world, no season is the same as the last or indeed the same as any previous season, nor will it be repeated in detail next time round. Most of these variations we take for granted; they add a lot of interest to our lives. Those we particularly notice are the extreme situations and the climate disasters. Most of the worst disasters in the world are, in fact, weather- or climate related.

Not all the climate changes will in the end be adverse. While some parts of the world experience more frequent or more severe droughts, floods or significant sea level rise, in other places crop yields may increase due to the fertilizing effect of carbon dioxide. Other places, perhaps for instance in the sub-arctic, may become more habitable. Even there, though, the likely rate of change will cause problems: large damage to buildings will occur in regions of melting permafrost, and trees in sub-arctic forests like trees elsewhere will not have time to adapt to new climatic regimes. Scientists are confident about the fact of global warming and climate change due to human activities. However, uncertainty remains about just how large the warming will be and what will be the patterns of change in different parts of the world. Although useful indications can be given, scientists cannot yet say in precise detail which regions will be most affected. Intensive research is needed to improve the confidence in scientific predictions (Houghton 2009).

Climate change is an increasingly urgent problem with potentially far-reaching consequences for life on earth. Humans and wildlife are also exposed to an array of chemical, physical, and biological stressors that arise largely from anthropogenic activity, but also from natural sources. One of the consequences of climate change that has recently attracted attention is its potential to alter the environmental distribution and biological effects of chemical toxicants. There is growing awareness of the importance of anticipating the effects of chemical pollution in the rapidly changing environment, and identifying and mitigating effects in those humans and ecosystems most vulnerable (Noyes et al. 2009).

Today, global climate change is a fact. The climate has changed visibly, tangibly, measurably. An additional increase in average temperatures is not only possible, but very probable, while human intervention in the natural climate system plays an important, if not decisive role (Porro 2002). Climate change is a major concern in relation to the minerals sector and sustainable development. It is, potentially, one of the greatest of all threats to the environment, to biodiversity and ultimately to our quality of life (FTF 2002).

Climate on Earth has changed many times during the existence of our planet, ranging from the ice ages to periods of warmth. During the last several decades increases in average air temperatures have been reported and associated effects on climate have been debated worldwide in a variety of forums. Due to its importance around the globe, agriculture was one of the first sectors to be studied in terms of potential impacts of climate change (Adams et al. 1990). According to studies carried out by IPCC, average air temperatures will increase between 1.4°C and 5.8°C by the end of this century, based upon modeling techniques that incorporated data from ocean and atmospheric behavior. The possible impacts of this study, however, are uncertain since processes such as heat, carbon, and radiation exchange among different ecosystems are still under investigation. Less drastic estimates predict temperature increase rates of 0.088°C per decade for this century (Kalnay and Cai 2003). Other investigators forecast for the near future that rising air temperature could induce more frequent occurrence of extreme drought, flooding or heat waves than in the past (Assad et al. 2004).

Studies of specific local impacts of climate changes have been conducted by hundreds of research groups, many from organizations concerned with such matters as seasonal crop forecasts, water supply and coastal protection. These groups have found that climate change and sea-level rise of the magnitude and rates suggested would greatly affect many natural systems like forests, rivers and wildlife, as well as human activities and society. Examples include: (1) changes in natural productivity and biodiversity, with an increased rate of extinctions, (2) decreases in cereal crop yields in most tropical and sub-tropical countries, and in temperate countries for large warmings, (3) increased water shortages in many water-scarce regions due to regional decreases in precipitation, increased evaporation and loss of glaciers and seasonal snow storages, (4) adverse economic effects in many developing countries for even small warmings, and for developed countries for larger warmings, (5) tens of million of people on small islands and low-lying coastal areas at severe risk of flooding from sea-level rise and storm surges, (6) increased threats to human health,

(7) increased inequities between poor and richer countries, (8) increased risk of abrupt and irreversible climate changes (Pittock 2009).

In conclusion, climate change impacts are complex in that they can be both direct and indirect. For example, more rain may lead directly to either greater or smaller crop yields, depending on factors such as the type of crop, the soil and the present climate. Indirect effects could include changes in supply and demand as a result of these larger or smaller yields, both regionally and globally, and the resulting changes in commodity prices, the profitability of farming, and the affordability of food and effects on human health. Moreover, impacts can often be made more favorable by changing strategies so as to minimize losses and maximize gains. It could be concluded that climate change is a blessing and a curse for agriculture.

3.5 The Climate of Egypt

Egypt has an arid desert climate. It is hot or warm during the day, and cool at night. In the coastal regions, temperature daytime temperatures range between an average of minimum 14°C (57°F) in winter and average of maximum 30°C (86°F) in summer. In deserts the temperature varies to a great degree, especially in summer; it may range from 7°C (44.6°F) at night, to 40°C (104.0°F) during the day. While the winter temperatures in deserts do not fluctuate as wildly, they can be as low as 0°C (32°F) at night, and as high as 18°C (64.4°F) during the day. Hot and dry Khamsin winds blow in the Nile Delta region Egypt receives less than 80 mm (3.15 in) of precipitation annually in most areas, although in the coastal areas it reaches 200 mm. It hardly ever rains during the summer (Table 3; Zahran and Willis 2009).

Although Egypt is an arid country, its climate was wet in geological times. The history of the climate in Egypt has been subject to many speculations based on inference from geomorphological and archaeological studies: see for example, Sandford (1934), Murray (1951) and Butzer (1959). Murray (1951) concludes that regular rainfall ceased over Egypt below the 500 m contour some time about the close of the Plio-Pleistocene period, three-quarters of a million years ago and, though torrents from the Red Sea Hills have been able to maintain their courses to the Nile through the foothills of the Eastern Desert, the Western Desert has ever since been exposed to erosion by wind alone. The earlier European glaciations seem to have left the Egyptian desert dry, but the long span of drought was broken by at least two rainy interludes; the first when the deserts, both east and west of the Nile, were habitable in Middle Palaeolithic times, the second, with light rainfall, from about 8000–4000 BC. An occurrence of subsoil water near the surface in the southern part of the Western Desert permitted people to live there in oases till about 3000 BC when a drop of the water-table rendered these places uninhabitable. The source of surface water all over the Eastern Desert is the rainfall on the chains of the Red Sea Mountains. These, mountains seem to intercept some orographic rain from the continental northerlies which absorb their moisture through passage over the warm water of the Red Sea. The

Table 3 Comparison among the total greenhouse gas indicators (emissions of CO_2, emissions per capita ratio and specific emission ratio) 1990/2000 in Egypt (Adapted from UNDP 2011)

Year	Population, million	GDP market price, billion US$	Emissions, million ton CO_2e	Emission ton CO_2e per capita	Emissions per capita ratio (2000/1990), %	Emission ton CO_2e per thousand US$	Specific emission ratio (2000/1990), %
1990	**52.6**	35.16	116.6	2.2	–	3.3	–
2000	**63.3**	99.74	193.3	3.1	137%	1.9	58

GDP gross domestic production, *US$* United States dollar mountain rains may feed the wadis of the Eastern Desert with considerable torrential flows (Zahran and Willis 2009).

According to Ayyad and Ghabbour (1986), Egypt can be divided into two hyper arid and two arid provinces as follows:

1. *Hyper arid provinces*:
   (a) Hyper arid with a mild winter, where mean temperature of the coldest month between 10°C and 20°C and a very hot summer with mean temperature of the hottest month more than 30°C, including the southwestern part of the Western Desert.
   (b) Hyper arid with a mild winter and a hot summer, i.e. mean temperature of the hottest month 20–30°C covering the Eastern Desert and the northeastern part of the Western Desert and Gebel Uweinat area.
2. *Arid provinces*:
   (a) The northern section with winter rainfall which extends along the Mediterranean coast and the Gulf of Suez. This section is divided into two provinces by the UNESCO/FAO map of 1963: the coastal belt province under the maritime influence of the Mediterranean, with a shorter dry period attenuated, and a more inland province with a longer dry period accentuated and an annual rainfall of 20–100 mm. Both provinces are characterized by a mild winter and a hot summer.
   (b) A southern section with winter rainfall which includes one province – the Gebel Elba area of the Red Sea coast of Egypt (Zahran and Willis 2009).

Therefore, Egypt has an arid desert climate. It is hot or warm during the day, and cool at night. In the coastal regions, temperature daytime temperatures range between an average of minimum 14°C in winter and average of maximum 30°C in summer. In deserts the temperature vary to a great degree, especially in summer; they may range from 7°C at night, to 40°C during the day. While the winter temperatures in deserts do not fluctuate as wildly, they can be as low as 0°C at night, and as high as 18°C during the day. Hot and dry Khamsin winds blow in the Nile Delta region. Egypt receives less than 80 mm of precipitation annually in most areas, although in the coastal areas it reaches 200 mm. It hardly ever rains during the summer. It could be also divided the climate of Egypt to hyper arid provinces and arid provinces.

3.6 Situation Analysis for Egypt and Climate Changes

Situation analysis of Egypt and climate changes has been reported as follows (UNDP 2011):

1. In 1994, Egypt ratified the United Nations Framework Convention on Climate Change (UNFCCC). The Intergovernmental Panel on Climate Change in its

Third assessment report, IPCC (1995), identified Egypt's Mediterranean coast and the Nile Delta as vulnerable regions to sea level rise. In this respect, Egypt set up the Climate Change institutional structure at the national level, and a Climate Change Unit was established in 1996 in Egyptian Environmental Affairs Agency.

2. In 2007, Egyptian Prime Minister issued Decree No. 272 to reform the National Climate Change Committee that was established in 1997. The new Climate Change Committee is chaired by the Minister of State for Environmental Affairs and includes members representing a wide range of governmental and nongovernmental representatives. In addition, Ministry of State for Environmental Affairs upgraded Climate Change Unit to be a Central Department in Egyptian Environmental Affairs Agency in 2009, in order to strengthen the climate change institutional structure on the national level.
3. Two ministerial climate change committees in the Ministry of Agriculture & Land Reclamation and the Ministry of Irrigation & Water Resources have been established. In addition, a climate change information centre in the Agriculture Research Centre has been established. However, many barriers still exist that are challenging Egypt efforts to comply with United Nations Framework Convention on Climate Change such as inadequate capacity and weak coordination and cooperation between governmental bodies, Non-governmental Organizations and private sector. Furthermore there is a lack of mainstreaming the adaptation measures in the national planning process, particularly in comparison with mitigation measures.
4. Egypt submitted Initial and Second National Communication reports to United Nations Framework Convention on Climate Change in 1999 and 2010, respectively. According to Initial National Communication and Second National Communication Egypt's most vulnerable sectors to climate change are identified as follows: (1) coastal zones, (2) water resources and (3) agriculture. The sea level rise is the cause of the most serious climate change impacts that threatens the densely populated River Nile Delta which includes extensive infrastructure and fertile agriculture lands. In this respect, sea level rise is expected to inundate large areas of low lying lands in the Nile Delta and sea water intrusion will increase water logging conditions and soil salinity in other lands. Furthermore, there is also a high degree of uncertainty regarding the climate change impacts on the annual Nile flood, the expected decline in precipitation along the North Coast and a projected increase in the population estimated between 115 and 179 million by 2050. Moreover, temperature rise is expected to reduce the productivity of major crops, increase crop water requirements coupled with an expected water stress and loss of some lands and fertility in the Nile Delta and consequently the overall food production may be significantly reduced. Impacts of climate change on other vulnerable sectors to climate change will be further investigated in the Third National Communication. Accordingly, climate change risks may threaten Egypt's efforts to achieve the Millennium Development Goals and to face those threats; Initial National Communication and Second National

Communication presented several adaptation measures to climate change impacts, as well as, many mitigation measures to play an effective role in achieving the main target of the United Nations Framework Convention on Climate Change.

Review information on vulnerability and impacts provided in the Second National Communication and re-confirm gaps in data collection and analysis for all areas, with special emphasis on the following four priority areas identified under the Second National Communication and designated by the Government as continuing priority areas for the Third National Communication:

- Agriculture updating data and analysis on cereal crops production, fibre crops; and livestock, as well as, study other new areas such as insects, plant disease and fisheries
- Water resources particularly new data and resulting analysis from the Regional Circulation Model that developed under Climate Change Risk Management Program
- Coastal Zones updating all related information to Sea Level Rise and its impacts on Costal areas in Egypt and particularly in Delta
- Studying new areas that were not covered in Second National Communication such as biodiversity. As well as, give more attention to health, human habitat & settlement and tourism that were not addressed adequately in Second National Communication (UNDP 2011).

From the previous, it could be concluded that the situation analysis of Egypt and climate changes started from ratification of Egypt to the United Nations Framework Convention on Climate Change in 1994, establishment of Climate Change Unit in 1996 in the Egyptian Environmental Affairs Agency, issue the Egyptian Prime Minister Decree No. 272 to reform the National Climate Change Committee in 2007, establishment of two ministerial climate change committees in the Ministry of Agriculture & Land Reclamation and the Ministry of Irrigation & Water Resources, and submission Egypt to Initial and Second National Communication reports to United Nations Framework Convention on Climate Change in 1999 and 2010, respectively.

4 Climate Changes and Agriculture in Egypt

The natural greenhouse effect raises the temperature of the planet to 33°C, thus making it habitable. On average, 343 W m^{-2} of sunlight fall on the earth, roughly 1/3 of which is reflected back into space. The other 2/3 reaches the ground, which re-radiates it as longer wavelength, infrared radiation. Some of this is blocked by greenhouse gases, thereby warming the atmosphere. Naturally occurring greenhouse gases include water vapor, CO_2, methane (CH_4) and nitrous oxide (N_2O). Reducing emissions of CO_2 could be achieved by switching to renewable energy (IPCC 1996).

Nature provides freshwater through the hydrologic cycle. The process is as follows: production of vapors above the surface of the liquids, the transport of vapors by winds, the cooling of air–vapor mixture, condensation and precipitation (Salem 2012).

In fact, climate is a primary determinant of agricultural productivity. In turn, food and fiber production is essential for sustaining and enhancing human welfare. Hence, agriculture has been a major concern in the discussions on climate change. Food supply vulnerability to climate change is an issue in two different ways. First, future food supply may be directly threatened by climate change. Second, food supply capacity may be altered by efforts to reduce greenhouse gases emissions as society tries to mitigate future implications of climate change. Agronomic and economic impacts from climate change depend primarily on two factors: (1) the rate and magnitude of change in climate attributes and the agricultural effects of these changes, and (2) the ability of agricultural production to adapt to changing environmental conditions (McCarthy et al. 2001).

Climate is the single most important determinant of agricultural productivity, primarily through its effects on temperature and water regimes. For example, the physiographic boundaries of principal biomes are determined by mean annual temperature and soil water regimes. Climate change is therefore expected to alter the biophysical environment of growing crops and to influence biomass productivity and agronomic yields (Rosenzweig and Hillel 1998).

Positive effects may be associated with the fertilization effects of CO_2 enrichment, increases in the duration of growing seasons in higher latitudes and mountain ecosystems, and possible increase in soil water availability in regions with an increase in annual precipitation. Each 1°C increase in temperature may lead to a 10-day increase in the growing season in northern Europe and Canada. The CO_2 fertilization effect is real. However, the net positive effect may be moderated by other factors, such as the effective rooting depth and nutrient availability. Further, the productivity per unit of available water is expected to rise by 20–40% (van de Geijn and Goudriaan 1996).

Negative effects of projected climate change on agriculture may be due to increases in respiration rate as temperature rises with attendant decreases in net primary productivity (NPP); increases in the incidence of pests and diseases; shortening of the growing period in some areas; decrease in water availability as rainfall patterns change; poor vernalization; and increased risks of soil degradation caused by erosion and possible decline in SOC concentration. The yield of rice has been estimated to decrease by 9% for each 1°C increase in temperature. Phillips et al. (1996), using the explicit planetary isentropic coordinate (EPIC) model to examine the sensitivity of corn and soybean yields to climate change, projected a 3% decrease in both corn and soybean yields in response to a 2°C increase in temperature from a baseline precipitation level. However, a 10% precipitation increase balanced the negative effect of a 2°C temperature increase. The effects of climate change on crop yields may be more negative at lower latitudes and generally positive at middle and high-middle latitudes. Further, crop growth is more affected by extremes of weather than by averages. The annual average changes in temperature or precipitation used in most predictive models do not reflect the short-term effects of so-called extreme events — droughts, floods, freezes, or heat waves (Lal 2005).

4.1 Climate Changes and Its Impact on Agriculture

Driven mainly by population and economic growth, total world food consumption is expected to increase over 50% by 2030 and may double by 2050 (Barker et al. 2007). Most of the increase in food production in the next decades is expected to occur through further intensification of current cropping systems rather than through opening of new land into agricultural production. Intensification of cropping systems has been a highly successful strategy for increasing food production. The best example is the well-known success of the *Green Revolution*, where the adoption of modern varieties, irrigation, fertilizers and agrochemicals resulted in dramatic increases in food production. However, this strategy also resulted in unexpected environmental consequences, one of them being the emissions of greenhouse gases into the atmosphere. Therefore, future strategies that promote further intensification of agriculture should aim at the development of sustainable cropping systems that not only consider increasing food production but that also look at minimizing environmental impact (Ortiz-Monasterio et al. 2010).

At present, 40% of the Earth's land surface is managed for cropland and pasture (Foley et al. 2005). The most important cropping systems globally, in terms of meeting future food demand, are those based on the staple crops, *rice, wheat and maize*. Rice and maize are each grown on more than 155 million ha (FAOSTAT 2009). In addition, rice is the staple food of the largest number of people on Earth. The geographic distribution of rice production gives particular significance to Asia where 90% of the world's rice is produced and consumed. Maize is produced mainly in the Americas, followed by Asia and then Africa. Maize is important as a staple crop (mainly in developing countries) but it is also important as animal feed and, increasingly, as biofuel. Wheat is the most widely grown crop, covering more than 215 million ha around the world, with Asia covering close to 50% of the world wheat area (FAOSTAT 2009).

Without additional policies, agricultural N_2O and CH_4 emissions are projected to increase by 35–60% and ~ 60%, respectively, to 2030, thus increasing more rapidly than the 14% increase of non-CO_2 greenhouse gases observed from 1990 to 2005 (Barker et al. 2007). Improved agricultural management enhances resource-use efficiencies, often reducing emissions of more than one greenhouse gas. The effectiveness of these practices depends on factors such as climate, soil type and farming system. About 90% of the total mitigation arises from sink enhancement (soil C sequestration) and about 10% from emission reduction. In spite of inherent uncertainties in such estimates, it can be concluded that the topic of this review, which addresses the second option (improved cropland management) and the fifth option (improved rice management), comprises a sizable portion of the overall mitigation potential of agriculture (Ortiz-Monasterio et al. 2010).

Promoting agricultural practices that mitigate climate change by reducing GHG emissions is important, but those same practices also have to improve farmer production and income and buffer the production system against the effects of changes in climate. The overall impact predicted by climate change models vary but we are now locked into global warming and inevitable changes to climatic pattern that are likely to exacerbate existing rainfall variability and further increase the frequency of

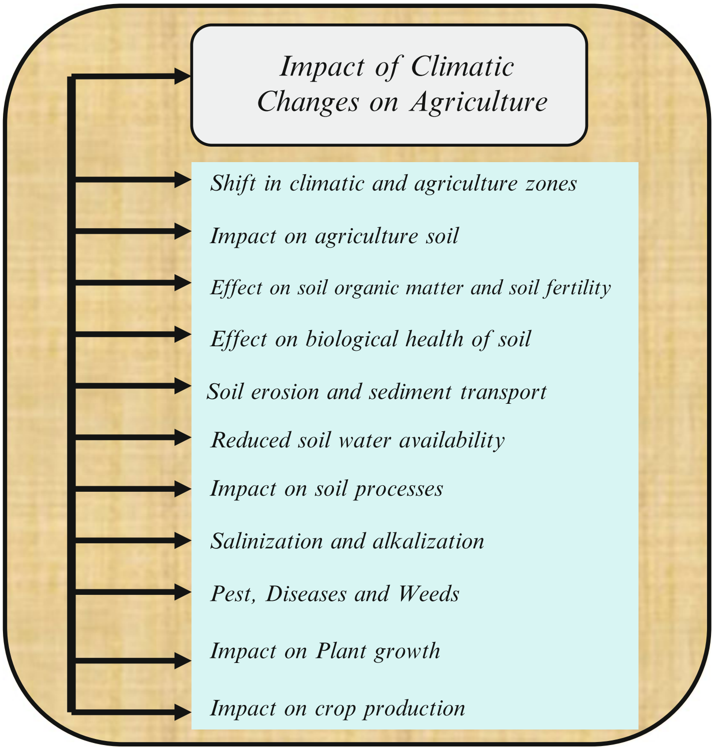


Fig. 4 Points that must be considered while doing the study of impacts of climatic changes on agriculture, which include soil, water, plant and the agroecosystem (Adapted from Khan et al. 2009)

climatic extremes. Where excess rain occurs, extreme rainfall events will increase leading to flooding and soil erosion. In low rainfall, drought-prone areas there is general acceptance in the science community of more frequent moisture stress because of failed rainfall patterns and increased evaporation caused by higher temperatures (Cooper et al. 2008). In Africa specifically, the projected combined impacts of climate change and population growth suggest an alarming increase in water scarcity for many countries, with 22 of the 28 countries considered likely to face water scarcity or water stress by 2025. This in turn will curtail the ability of irrigated agriculture to respond to the expanding food requirements of tomorrow's Africa (Rosegrant et al. 2002).

In order to cope with the increased climate risk, agricultural systems will have to be more robust and resilient to buffer for extreme weather events such as drought, flooding, etc. (Fig. 4). It is paramount that new agricultural practices not only prevent further soil degradation but also improve system resilience through increased soil organic matter, improved water-use efficiency as well as nutrient-use efficiency, and increased flora and fauna biodiversity. However, the management of agriculture to cope with greenhouse gases emissions and the negative effects of climate change on food production lies in the hands of farmers, pastoralists and forest managers whose decisions are determined by multiple goals (Hobbs and Govaerts 2010).

The impacts of climate change on agriculture are expected to be widespread across the globe, although studies suggest that African agriculture is likely to be most affected due to heavy reliance on low-input rainfed agriculture and due to its low adaptive capacity (Mertz et al. 2009). Broadly speaking, climate change is likely to impact crop productivity directly through changes in the growing environment, but also indirectly through shifts in the geography and prevalence of agricultural pests and diseases, associated impacts on soil fertility and biological function, and associated agricultural biodiversity. While many impact predictions tend towards the negative, increased CO_2 will also contribute to enhanced fertilization – although there is significant debate as to the extent to which this may increase plant growth. This section looks at these issues, concentrating entirely on the expected biophysical impacts (Jarvis et al. 2010).

Climate change due to anthropogenically-generated greenhouse gases and aerosols has been recognized as a serious threat to the earth's ecosystems and its inhabitants, and the dangers associated with climate change will increase in severity in coming decades in the absence of measures to curb the production of the responsible pollutants e.g., carbon dioxide, methane, nitrous oxide. Numerous scientific articles and peer-reviewed reports have demonstrated the current and potential future effects of the climate change that result from these increased greenhouse gas emissions (IPCC 2007).

Among the resource sectors that received early attention regarding possible climate change effects has been agriculture and it has continued to receive considerable attention since that early research. Work in this area has become more sophisticated over time and is now connected explicitly to estimates of economics in the agricultural sector (Reilly 2010) and risk of hunger. As is the case with many impact areas, studies of possible adaptation to climate change have come to the fore and become increasingly important (Easterling 2010), and this is particularly striking for agriculture where studies of adaptation to climate change appeared early in the history of climate change research. The importance of adaptation studies has also put more emphasis on the need for more detailed information regarding future regional climate change (Mearns 2011).

It could be concluded that climate change and agriculture are interrelated processes, both of which take place on a global scale. At the same time, agriculture has been shown to produce significant effects on climate change, primarily through the production and release of greenhouse gases such as CO_2, CH_4, and nitrous oxide, but also by altering the Earth's land cover, which can change its ability to absorb or reflect heat and light, thus contributing to radiative forcing. Land use change such as deforestation and desertification, together with use of fossil fuels, are the major anthropogenic sources of CO_2; agriculture itself is the major contributor to increasing CH_4 and nitrous oxide concentrations in Earth's atmosphere. Agronomic and economic impacts from climate change depend primarily on two factors: (1) the rate and magnitude of change in climate attributes and the agricultural effects of these changes, and (2) the ability of agricultural production to adapt to changing environmental conditions. Temperature, precipitation, atmospheric carbon dioxide content, the incidence of extreme events and sea level rise are the main climate change related drivers which impact agricultural production. Briefly, the main categories of agricultural productivity implications are: crops and forage productivity and production cost, soil suitability for agricultural production, livestock productivity and production cost and irrigation water supply.

4.2 Climate Change's Impacts on Global Crop Productivity

The major concerns for crop productivity as a result of increased levels of greenhouse gases are related to warmer temperatures and altered amounts and patterns of rainfall. Both average temperature and temperature variability are predicted to increase. Average global temperatures are predicted to increase by 0.6–2.5°C over the next 50 years with significant spatial variation. While this will permit cultivation of crops in areas of the world which are currently too cold e.g. Siberia and northern America and extend the potential growing season for others, it will also threaten the viability of crops in many of the major areas of production. Simulation models suggest that wheat yields in south-east Australia may decrease by about 29% (Anwar et al. 2007) and direct studies in the Philippines have shown that irrigated rice yields decrease by 10% for each 1°C increase in the minimum night-time temperature although the maximum temperature has no effect (Peng et al. 2004).

Higher temperatures will shorten the life cycle of most crops, by accelerating development and hastening senescence, thereby decreasing the time available to harvest light and produce biomass. The effects on phenology vary both between species and with environment. Perennial crops may respond more strongly to an increased temperature than annual crops (Estrella et al. 2007). Other effects such as drought or an increase in ozone concentrations can exacerbate these effects. The decreased time available to harvest light and produce biomass contributes to yield reductions at elevated temperatures (Parry and Hawkesford 2010).

Our knowledge of water use is as poor as our knowledge of water resources perhaps poorer. Information is largely incomplete particularly for agriculture, the largest user and is lacking altogether for some countries. Only limited disaggregated information exists, and even this shows deficiencies of validity and homogeneity and provides extremely poor information on trends. The quality of information systems varies with each country, but there are common difficulties: (1) Statistics on the magnitude of demand and withdrawal are often estimated rather than based on data that are measured or collected from censuses. The level of uncertainty varies, but is particularly high for agriculture. (2) Sectors of use are not defined homogeneously and are not well disaggregated. (3) Adequate historical datasets are rare, and the dates of available statistics are not always explicit. (4) Lack of agreed terminology leads to discrepancies in data compilation and analyses. Agriculture is by far the main user of water. Irrigated agriculture accounts for 70% of water withdrawals, which can rise to more than 80% in some regions. Although increasing in urbanized economies, industrial including energy use accounts for only 20% of total water use and domestic use for about 10%. Water withdrawals for energy generation, hydropower and thermo-cooling are on the rise, but energy is one of the economic sectors that consumes the least water and it returns most of the water withdrawn back to the water system (about 95%). This is only a partial picture of sectoral usage as there are many unaccounted-for uses. Little is known about water use in informal urban settlements or informal irrigation systems, both of which are generally unaccounted for in official statistics (Connor et al. 2009).

Nowadays, climate changes, their causes and consequences, gained importance in many other areas of interest for sustainable life on Earth. The subject is, however, controversial. Understanding how climate changes will impact mankind in the decades to come is of paramount importance for our survival. Temperature, carbon dioxide (CO_2) and ozone (O_3) directly and indirectly affect the production and quality of fruit and vegetable crops grown in different climates around the world. Temperature variation can directly affect crop photosynthesis, and a rise in global temperatures can be expected to have significant impact on postharvest quality by altering important quality parameters such as synthesis of sugars, organic acids, antioxidant compounds and firmness. Rising levels of CO_2 also contribute to global warming, by entrapping heat in the atmosphere. Prolonged exposure to concentrations could induce higher incidences of tuber malformation and increased levels of sugars in potato and diminished protein and mineral contents, leading to loss of nutritional and sensory quality. Increased levels of O_3 in the atmosphere can lead to detrimental effects on postharvest quality of fruit and vegetable crops. Elevated levels of O_3 can induce visual injury and physiological disorders in different species, as well as significant changes in dry matter, reducing sugars, citric and malic acid, among other important quality parameters (Moretti et al. 2010).

Besides increase in temperature and its associated effects, climate changes are also a consequence of alterations in the composition of gaseous constituents in the atmosphere. CO_2, also known as the most important greenhouse gas, and O_3 concentrations in the atmosphere are changing during the last decade and are affecting many aspects of fruit and vegetable crops production around the globe (Felzer et al. 2007).

Exposure to elevated temperatures can cause morphological, anatomical, physiological, and, ultimately, biochemical changes in plant tissues and, as a consequence, can affect growth and development of different plant organs. These events can cause drastic reductions in commercial yield. However, by understanding plant tissues physiological responses to high temperatures, mechanisms of heat tolerances and possible strategies to improve yield, it is possible to predict reactions that will take place in the different steps of fruit and vegetable crops production, harvest and postharvest (Kays 1997). Temperature increase and the effects of greenhouse gases are among the most important issues associated with climate change. Studies have shown that the production and quality of fresh fruit and vegetable crops can be directly and indirectly affected by high temperatures and exposure to elevated levels of carbon dioxide and ozone. Temperature increase affects photosynthesis directly, causing alterations in sugars, organic acids, and flavonoids contents, firmness and antioxidant activity. Higher temperatures can increase the capacity of air to absorb water vapor and, consequently, generate a higher demand for water. Higher evapotranspiration indices could lower or deplete the water reservoir in soils, creating water stress in plants during dry seasons. For example, water stress is of great concern in fruit production, because trees are not irrigated in many production areas around the world. It is well documented that water stress not only reduces crop productivity but also tends to accelerate fruit ripening (Henson 2008).

Carbon dioxide concentrations are increasing in the atmosphere during the last decades (Mearns 2000). The current atmospheric CO_2 concentration is higher than at any time in the past 420,000 years (Petit et al. 1999). Further increases due to anthropogenic activities have been predicted. Carbon dioxide concentrations are expected to be 100% higher in 2100 than the one observed at the pre-industrial era (IPCC 2007). Ozone concentration in the atmosphere is also increasing. Even low-levels of ozone in the vicinities of big cities can cause visible injuries to plant tissues as well as physiological alterations (Felzer et al. 2007). Carbon dioxide accumulation in the atmosphere has directly effects on postharvest quality causing tuber malformation, occurrence of common scab, and changes in reducing sugars contents on potatoes. High concentrations of atmospheric ozone can potentially cause reduction in the photosynthetic process, growth and biomass accumulation. Ozone-enriched atmospheres increased vitamin C content and decreased emissions of volatile esters on strawberries. Tomatoes exposed to ozone concentrations ranging from 0.005 to 1.0 μ mol mol^{-1} had a transient increase in β-carotene, lutein and lycopene contents.

IPCC (2007) concluded that 'in mid- to high latitude regions, moderate warming benefits crop and pasture yields, but even slight warming decreases yields in seasonally dry and low-latitude regions, i.e. medium confidence'. In IPCC language, moderate warming is in the range of 1–3°C. Smallholder and subsistence farmers, pastoralists and artisanal fisher-folk will suffer complex, localized impacts of climate change, i.e. high confidence. Food and forestry trades are projected to increase in response to climate change with increased dependence on food imports for most developing countries, i.e. medium to low confidence. The report further concluded that warming beyond 2–3°C was likely to result in yield declines in all areas. This analysis was based on a synthesis of 69 studies, which was a vast improvement on the handful of studies used in the Third Assessment Report, AR3 (IPCC 2001).

But even since the IPCC, AR4 (2007) there has been a much larger number of studies which examine the impacts of climate change on crop production and yields, including global multi-crop studies, down to regional and national studies on individual crops. This chapter summarizes the IPCC findings, and provides a more detailed analysis of impact studies arising from 2006 to 2009. There are fairly consistent pictures drawn by different studies that show the potential effects of changing climates (Lobell et al. 2008). These all show steeply increasing trends in adverse impacts, particularly in food insecure regions among the tropics, which are likely to increase the extent to which these regions are food insecure, especially taking into account that most of these regions present the least adaptive capacity (Jarvis et al. 2010).

Grain yields are expected to fall in developing countries; however, the opposite is likely to happen in developed countries (IPCC 2007). Geographies of changes may influence yield responses: in high latitudes, where most of the developed countries are located, increased temperatures could increase the duration of growing seasons, thus benefiting farmers. However, in developing countries, which are mostly located in the tropics, this effect would not be observed. Investment capacity within the different agricultural sectors needs to be considered if yield losses are to be offset. Moreover, yield reductions will certainly result in increases in prices of agricultural goods, and this impact will be greater for food insecure regions (Jarvis et al. 2010).

Therefore, the major concerns for crop productivity as a result of increased levels of greenhouse gases are related to warmer temperatures and altered amounts and patterns of rainfall. Higher temperatures will shorten the life cycle of most crops, by accelerating development and hastening senescence, thereby decreasing the time available to harvest light and produce biomass. The effects on phenology vary both between species and with environment and perennial crops may respond more strongly to an increased temperature than annual crops. Other effects such as drought or an increase in ozone concentrations can exacerbate these effects. The decreased time available to harvest light and produce biomass contributes to yield reductions at elevated temperatures.

4.3 Impacts of Climate Changes on Crop Physiology

Agriculture accounts for 70% of freshwater withdrawals from rivers, lakes and aquifers up to more than 90% in some developing countries. Furthermore, unlike in industrial and domestic uses, where most of the water returns to rivers after use, in agriculture a large part of water is consumed by evapotranspiration. Many irrigation systems, however, return a large amount of water to the system after use. Biomass cannot be produced without water. The source of all food is photosynthesis. Biomass is processed through the food chain, which describes the flow of energy and feeding relationship between species: from primary producers, i.e. plants to herbivores to carnivores. It could be estimated how much water is needed to sustain our diets by calculating the water lost in evapotranspiration based on crop physiology. Depending on local climate, varieties and agronomical practices, it takes 400–2,000 l of evapotranspiration daily to produce 1 kilogram (kg) of wheat, and 1,000–20,000 l per kilogram of meat, depending on the type of animal, feed and management practices. Based on these values, researchers have estimated daily water requirements to support diets, ranging from 2,000 to 5,000 l of water per person per day. FAO uses 2,800 kilocalories (kcal) per person at the national level as a threshold for food security. As a rule of thumb, it can therefore be estimated that 1 l of water is needed to produce 1 kcal of food. Because of the low energy efficiency of the food chain, protein-rich diets require substantially more water than vegetarian diets (Connor et al. 2009).

Over the past 800,000 years, atmospheric (CO_2) changed between 180 ppm (glacial periods) and 280 ppm (interglacial periods) as Earth moved between ice ages. From pre-industrial levels of 280 ppm, (CO_2) has increased steadily to 384 ppm in 2009, and mean temperature has increased by 0.76°C over the same time period. Projections to the end of this century suggest that atmospheric (CO_2) will top 700 ppm or more, whereas global temperature will increase by 1.8–4.0°C, depending on the greenhouse emission scenario (IPCC 2007). There is growing evidence suggesting that many crops, notably C_3 crops, may respond positively to increased atmospheric CO_2 in the absence of other stressful conditions (Long et al. 2004), but the beneficial direct impact of elevated CO_2 can be offset by other effects of climate change, such as elevated temperatures, higher tropospheric ozone concentrations and altered patterns of precipitation (Easterling et al. 2007; Da Matta et al. 2010).

It is now universally accepted that increased atmospheric concentrations of 'greenhouse gases' are the main cause of the ongoing climate change (Forster et al. 2007) and that these changes are expected to have important effects on different economic sectors, e.g. agriculture, forestry, energy consumptions, tourism, etc. (Hanson et al. 2007). Since agricultural practices are climate-dependent and yields vary from year to year depending on climate variability, the agricultural sector is particularly exposed to changes in climate. In Europe, the present climatic trend indicates that in the northern areas, climate change may primarily have positive effects through increases in productivity and in the range of species grown (Alcamo et al. 2007), while in southern areas (i.e. the Mediterranean basin) the disadvantages will predominate with lower harvestable yields, higher yield variability and a reduction in suitable areas for traditional crops (Moriondo et al. 2010).

For climate change impact assessment, crop growth models have been widely used to evaluate crop responses, i. e. development, growth and yield by combining future climate conditions, obtained from General or Regional Circulation Models, with the simulation of CO_2 physiological effects, derived from crop experiments (Ainsworth and Long 2005). Many of these impact studies were aimed at assessing crop development shifts and yield variations under changes in mean climate conditions. These analyses showed that increasing temperatures generally shortened the growing period of commercial crops (Giannakopoulos et al. 2009), resulting in a shorter time for biomass accumulation. On the other hand, changes in yields were not homogeneous and dependent on crop phenology, e.g. summer and winter crops, crop type, e.g. C_3 and C_4 plants or environmental conditions, e. g. water and nutrient availability (Moriondo et al. 2010).

Other studies stressed that changes in climate variability, as can be expected in a warmer climate, may have a more profound effect on yield than changes in mean climate (Porter and Semenov 2005). As such, policy analysis should not rely on scenarios of future climate involving only changes in means. Furthermore, the changes in the frequency of extreme climatic events during the more sensitive growth stages have been recognized as a major yield-determining factor for some regions in the future (Easterling and Apps 2005; Schneider et al. 2007). Temperatures outside the range of those typically expected during the growing season may have severe consequences on crops, and when occurring during key development stages they may have a dramatic impact on final production, even in case of generally favorable weather conditions for the rest of the growing season. Many studies highlighted the potential of heat stresses during the anthesis stage as a yield reducing factor (Challinor et al. 2005), while others pointed out that the joint probability of heat stress-anthesis is likely to increase in future scenarios (Alcamo et al. 2007). Accordingly, both changes in mean climate and climate variability including extreme events should be considered for a reliable climate change impact assessment in agriculture. An example is the summer heat wave of 2003 (Schaer et al. 2004), taken as an indicator of the future climate change, which reduced cereal production in Europe by 23 MT with respect to 2002. The reason for this reduction was attributed to the shorter growing season combined with a higher frequency of extreme events, both in terms of maximum temperatures and longer dry spells (Olesen and Bindi 2004). In contrast, climate change impact assessments carried out so far have not included direct simulations of heat stress impact on crop yield (Schneider et al. 2007) resulting in a probable underestimation of yield losses (Moriondo et al. 2010).

The temperature response of crop growth and yield must be considered to predict the (CO_2) effects. The threshold developmental responses of crops to temperature are often well defined, changing direction over a narrow temperature (Porter and Semenov 2005). High temperatures reduce the net carbon gain in C_3 species by increasing photorespiration; by reducing photorespiration, (CO_2) enrichment is expected to increase photosynthesis more at high than at low temperatures, and thus at least partially offsetting the temperature effects of supra-optimal temperatures on yield. Therefore, yield increases at high (CO_2) should occur most frequently in regions where temperatures approximate the optimum for crop growth. Conversely, in regions where high temperatures already are severely limiting, further increases in temperature will depress crop yield regardless of changes in (CO_2) (Polley 2002). In fact, results of mathematical modeling suggest that, in mid- to high-latitude regions, moderate to medium local increases in temperature (1–3°C), along with associated CO_2 increase and rainfall changes, can have beneficial impacts on crop yields, but in low-latitude regions even moderate temperature increases (1–2°C) are likely to have negative impacts on yield of major cereals (Easterling et al. 2007). Thus, climate change may impair food production, particularly in developing countries, most of which are located in tropical regions with warmer baseline climates (Da Matta et al. 2010).

In addition to crop growth and yield, crop quality is also expected to be affected by global climatic changes. Crop quality is thought to be a multi-faceted and complex subject involving growth, assimilate partitioning and storage, and pre- and post-harvest, including nutritional, technological and environmental facets (Hay and Porter 2006). Elemental, e.g. zinc, iodine and macromolecular, e.g. protein composition in plant tissues are expected to change in a future high-CO_2 world (Taub et al. 2008). In this context, crop physiologists will need to take more account of the interests of breeders and processors by studying, quantifying and modeling the differences not only in increasing yields but also in food quality among crop varieties and species in climate change scenarios (Hay and Porter 2006). The efforts to understand the impact of elevated (CO_2), temperature and other ongoing climatic changes on food crops are crucial to estimate food production in the future. The present review, which is by no means exhaustive, is mainly focused on the current understanding of the consequences of climatic changes (mainly CO_2 enrichment and temperature) on crop physiology and chemistry (Da Matta et al. 2010).

Crops sense and respond directly to rising (CO_2) through photosynthesis and stomatal conductance, and this is the basis for the CO_2 fertilization effect on crop yield (Long et al. 2006). These responses are highly dependent on temperature (Polley 2002). Therefore, understanding how crop species will respond to these environmental changes is crucial for maximizing the potential benefits of elevated CO_2, for which agronomic practice needs to adapt as both temperature and CO_2 rise (Challinor and Wheeler 2008). In fact, both chemical and microbiological risks are foreseen to impair food and feed safety as a consequence of climate change: in particular, mycotoxins, pesticide residues, trace metals and other chemicals could affect food and feed safety (Miraglia et al. 2009). There is, therefore, an urgent need for scientific research that can improve our understanding of the interactions of rising atmospheric (CO_2) with other environmental variables, such as temperature, water supply and ozone concentration, as well as with biotic factors such as pests and diseases, under real field conditions. In doing so, it is necessary not only to quantify the effects of climatic changes on crop production but also on food quality. It is also necessary to assess responses of crops other than the key cereal grains, and in climate regions other than temperate ones, notably those of importance to developing countries in the tropics and subtropics (Tubiello et al. 2007). Furthermore, since distinct varieties seem to respond differently to elevated CO_2 and temperature in terms of harvestable yield, future research should be also directed towards selecting promising genotypes for a changing global climate (Da Matta et al. 2010).

From previous, it could be concluded that now universally is accepted that increased atmospheric concentrations of greenhouse gases are the main cause of the ongoing climate change and that these changes are expected to have important effects on different economic sectors, e.g. agriculture, forestry, energy consumptions, tourism, etc. The increasing temperatures generally shortened the growing period of commercial crops, resulting in a shorter time for biomass accumulation. The changes in yields are not homogeneous and dependent on crop phenology, e.g. summer and winter crops, crop type, e.g. C_3 and C_4 plants or environmental conditions, e. g. water and nutrient availability.

4.4 Effects of Climatic and Global Change on Water Scarcity

Egypt has already reached the water poverty limit and needs a much greater share of Nile water in year 2050 to cover the shortage. Surface freshwater pollution has embarked on a critical path. One climate change scenario predicts that the Nile discharge may decrease to 3/4 of its present volume if CO_2 emissions double. Low cost solar water desalination is a strategic solution for Egypt. The number of desalination plants has increased in the last 30 years and generated 2333.963 m^3 day^{-1} in 2004 (SRU 2006). There is a trend in Egypt to apply desalination to meet the requirements of industry, tourism, petroleum, electricity, health and reconstruction. The desalination plants are located on the Red Sea coast, in south Sinai and on the northern coast (Salim 2012).

Climate change projections also indicate an increased likelihood of droughts and variability of precipitation – in time, space, and intensity – that would directly influence water resources availability. The combination of long-term change, e. g. warmer average temperatures and greater extremes, e. g. droughts can have decisive impacts on water demand, with further impact on the ecosystems. Under all climate change scenarios in the Mediterranean region, available water resources decrease while irrigation demand increases (Iglesias et al. 2007).

Climate change drives much of the change evident in natural hydrological cycles, which is one of the greatest environmental, social and economic threats facing the planet. Recent warming of the climate system, irrespective of the causes is indisputable, and is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level. IPCC (2007) concludes that observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases. Other effects of regional climate changes on natural and human environments are emerging, although many are difficult to discern due to adaptation and non-climatic drivers.

Anticipated impacts of climate change on fresh water resources and their management are reported to be as follows (IPCC 2007):

- By mid-century, annual average river runoff and water availability are projected to increase by 10–40% at high latitudes and in some wet tropical areas, and decrease by 10–30% over some dry regions at mid-latitudes and in the dry tropics, some of which are presently water stressed areas. In some places and in particular seasons, changes differ from these annual figures.
- Drought-affected or water stressed areas will likely increase in extent.
- Heavy precipitation events are very likely to increase in frequency and intensity, and thus to augment flood risks.
- In the course of the century, water supplies stored in glaciers and snow cover are projected to decline, reducing water availability in regions supplied by meltwater from major mountain ranges, where more than one-sixth of the world population currently lives.

Impacts of climate change are of diverse nature. They refer to losses in biodiversity due to changes in environmental conditions affecting the ecosystems. The present boundaries of natural ecosystems may change due to modifications in climate regimes; actual crop patterns may have to be modified due to changes in environmental conditions influencing the crop cycles, development and production. Rainfed crops are therefore more vulnerable than irrigated ones due to changes in precipitation, infiltration, evapotranspiration and soil moisture regimes. Food security is therefore threatened in more vulnerable regions and countries of the world.

Changes in rainfall regimes will induce changes in stream flow regimes and lower base flow is expected. Moreover, the water quality regimes will also change and contamination impacts may be larger, affecting public health. The latter may also be impacted due to increase of frequency and severity of heat waves and wildfires. Overall, the water availability is expected to decrease thus enhancing competition among users and making it more difficult to satisfy the increased urban water demand for residents and tourism. It is important to recognize climate change as a process driving exacerbated water scarcity and threatening development in developing countries. Unfortunately, many other processes and driving forces are contributing to degradation of Earth's environment and people's welfare, including devastating wars. Nowadays, it is possible to identify within regions several situations that are expected to arise due to climate change (Pereira et al. 2009).

Water scarce regions are highly vulnerable to climate change impacts. Coping with water scarcity involves therefore requires that such impacts be recognized and appropriate mitigation and adaptation measures be developed and implemented to effectively cope with it. In general with the increase in temperature it is likely that there will be an increase of potential evapotranspiration and therefore a higher vegetation and crops demand for water as well as impacts due to heat waves.

Briefly, the impacts of climate change on fresh water resources and their management can be concluded that the annual average river runoff and water availability are projected to increase by 10–40% at high latitudes and in some wet tropical areas, and decrease by 10–30% over some dry regions at mid-latitudes and in the dry tropics. Drought-affected or water stressed areas will likely increase in extent and heavy precipitation events are very likely to increase in frequency and intensity, and thus to augment flood risks. And finally, water supplies stored in glaciers and snow cover are projected to decline, reducing water availability in regions supplied by meltwater from major mountain ranges, where more than one-sixth of the world population currently lives.

4.5 The Challenges Egypt Faces with Regard to Water and Agricultural Development

Egypt, like any other arid country, faces the pressing challenge of closing the gap between its limited water resources and the increasing water demand. Egypt considers the River Nile its '*vein of life*', being the sole source that covers nearly 95% of the population requirements. The dependence of the other nine riparian countries on the Nile water varies according to each country's precipitation and water use patterns. These countries, being mostly humid and/or less populated than Egypt, are less vulnerable to fluctuations of the Nile flows. Despite the fact that declining Nile water availability with respect to growing populations and increasing requirements for development is an alarming issue, Egypt has not yet reached the stage of a crisis. The principal water management challenges in Egypt stem from the nature and quality of supply and demand management responses to water shortage.

Table 4 Estimated water balance (in km^3 year^{-1}) of Egypt in 1997 and 2017 from Ministry of Water Resources and Irrigation through making a comparison between resources and demand water (Adapted from Adly and Ahmed 2009)

	Water resources			Water demand	
Items	1997	2017	Items	1997	2017
From lake Nasser through high Aswan dam	55.5	55.5	Agriculture	57.8	63.6
Rainfall	1.3	1.3	Domestic	4.7	6.6
Shallow groundwater	6.1	8.4	Industry	7.5	18.7
Drainage reuse	7.5	11.4	Navigation	0.2	0.2
Wastewater reuse	1.4	2.4	Evaporation	2.4	2.5
Total	**71.8**	79.0	Fishery	1.3	0.6
Industrial water flushed back to system	6.8	17.8	**Total**	**73.9**	**92.2**
Agricultural water flushed back to system (not including reuse)	4.9	1.9	Drainage to sea	12.9	9.5
Domestic water flushed back to system (not including reuse)	2.4	2.6			
Fishery water flushed back to system	0.9	0.4			
Total water resources	86.8	101.7	**Total water demand**	86.8	101.7

Table 4 shows the water demand in Egypt in 1997 and that projected for 2017, demonstrating how these requirements will be met through tapping non-conventional water resources, including water savings and possibilities of reuse. Water conditions are, however, likely to straighten despite the giant water storage reservoir in Lake Nasser created after the construction of the High Aswan Dam in 1964. This is due to climatic fluctuations, accelerating development activities, and high price of untraditional water abstractions. The role of the High Aswan Dam in reducing Egypt's vulnerability to the fluctuations of external and shared resources originating from upstream countries cannot, nonetheless, be denied (Adly and Ahmed 2009).

The challenges facing all stakeholders led to recommendations based on manifold expertise and a willingness to start where others have ended. The cooperation within the Nile Basin Initiative offers a platform for partnership and a shared vision. There is a need to develop national integrated programs for water resources management. The civil society has an important role to play especially in the areas of water conservation and sustainable livelihoods through food security. And it would be appropriate in this context to recall the goal of the Nile Basin Discourse "to promote dialogue on sustainable and equitable development, peace and mutual understanding within the Nile River Basin". These data point out the need for coordination and effort unification among all Nile basin countries to reach unconventional solutions in facing the problem of the declining individual share of water supply, including improved water conservation, waste minimization and reuse of treated sewage water, besides a rationalization of the water demand (Adly and Ahmed 2009).

Managing water resources will become a more complex endeavor with climate change. Analysis predicts that climate change will intensify and accelerate the hydrological cycle, which will result in more water being available in some parts of the world and less water being available in other parts of the world (most of the developing world). Weather patterns are predicted to be more extreme. Those regions adversely affected will experience droughts and/or possible flooding. Is Egypt vulnerable? The answer is yes. The Nile waters are highly sensitive to climate change, both in amount of rainfall and variations in temperature. And since these two factors are also interrelated, i.e., temperature changes affecting rainfall, it can be expected that climate change will take the form of changes in levels of precipitation as a result of changes in temperature, or other factors, and that the resulting effect on the Nile flows will be from moderate to extreme, with the latter scenario most likely in the long term (Elsaeed 2012).

In conclusion, Egypt faces the pressing challenge of closing the gap between its limited water resources and the increasing water demand. Egypt considers the River Nile its vein of life, being the sole source that covers nearly 95% of the population requirements. The Nile waters are highly sensitive to climate change, both in amount of rainfall and variations in temperature. And since these two factors are also interrelated, i.e., temperature changes affecting rainfall, it can be expected that climate change will take the form of changes in levels of precipitation as a result of changes in temperature, or other factors, and that the resulting effect on the Nile flows will be from moderate to extreme, with the latter scenario most likely in the long term.

4.6 Climate Changes and Nile Water Availability in Egypt

Any assessment of Egypt's water resources recognizes the country's enormous reliance on the Nile, which makes up about 95% of Egypt's water budget. Other sources of Egypt's water budget, precipitation and ground water, do not make up more than 5% of the available supply, although the effect of increases or decreases in precipitation near the sources of the Nile can have a larger than expected effect on Nile flows. Egypt's total water budget is produced by a combination of three variables: the Nile (95%), precipitation (3.5%) and ground water (1.5%). The Nile produces 55.5 billion m^3, while the latter two variables combine to form safely about 2.2 billion m^3 of fresh water. In total, Egypt has available fresh water reserves of 58 billion m^3. Egypt's annual water demand is about 77 billion m^3. The deficit between Egypt's water supply and demand must be met through recycling. The 19 billion m^3 deficit is filled by a combination of treated sewage and industrial effluent, i.e. 4 billion m^3 and recycling used water, mainly from agriculture, i.e. 8 billion m^3. An additional 4 billion m^3 is extracted from the shallow aquifer and 3 billion m^3 comes from the Al Salam Canal Project (Elsaeed 2012).

Recycling is partly natural and partly intentional. Water reclaimed from agriculture is a natural process of drainage waters returning to the Nile. The remaining two sources of recycled water, the Al Salam Canal and extraction from the shallow aquifer, are manmade solutions to the deficit. Consumption of the 77 billion m^3 in annual water demand in Egypt is mainly from agriculture, i.e. 62 billion m^3. An additional 10%, i.e. 8 billion m^3 is used as drinking water. Approximately 95% of the population relies on this water for drinking purposes. The remaining demand comes from industry, i.e. 7.5 billion m^3. This section will focus on the impact of climate change on water supply and the potential challenges Egypt will face in the future if the balance between water supply and demand is altered (Elsaeed 2012).

Egypt's climate is semi-desert, characterized by hot dry summers, moderate winters, and very little rainfall. The country has areas with strong wind, especially along the Red Sea and Mediterranean coasts. Sites with an annual average wind speed of 8.0–10.0 m sec^{-1} have been identified along the Red Sea coast and about 6.0–6.5 m sec^{-1} along the Mediterranean coast. Average precipitation in the Ethiopian highlands, where much of the water in the Nile originates is highest in July, August, and September, at 5.4 mm day^{-1}, and almost negligible between January and March. Egypt is fairly unique in the distribution of its population, land-use and agriculture, and economic activity which makes it extremely vulnerable to any potential impacts on its water resources and coastal zone. Despite being a large rectangular shaped country with an area of about a million square kilometers, its lifelines are constrained along a narrow T-shaped strip of land, which constitutes less than 5% of its land area along the Nile and the coast around the Nile delta. The Nile supplies 95% of the country's total water needs, including water intensive irrigated agriculture along its banks and the delta. Agriculture is quite critical to the national economy as it employs 30% of the work force and contributes 17% to the Gross National Product (GNP). Major urban centers, commerce, and industrial activity are also confined to the narrow corridor along the Nile and the coast around its delta. The rest of the country is desert and does not support much population or economic (Agrawala et al. 2004)

The potential impacts of climate change on coastal resources are ranked as most serious. Sea levels are already rising in the Nile delta due to a combination of factors including coastal subduction and reduced sediment loads due to the construction of the High Aswan Dam upstream. Climate change induced sea-level rise only reinforces this trend. In addition to this high biophysical exposure to the risk of sea level rise, Egypt's social sensitivity to sea level rise is particularly high. As discussed earlier in this section much of Egypt's infrastructure and development is along the low coastal lands and the fertile Nile delta also constitutes the prime agricultural land in Egypt. The loss of this land due to coastal inundation or to saline intrusion will therefore have a direct impact on agriculture, which in turn is critical to Egypt's economy.

Egypt's Nile delta with its coastal front on the Mediterranean is considered vulnerable to the impacts of climate change. In addition to expected rise in sea-level, shoreline erosion, stresses on fisheries and saltwater intrusion in groundwater create major challenges. These factors also produce stressful effects on water and agricultural resources, tourism and human settlements. Fragile and unique ecosystems such as the mangrove stands in the Red Sea, which stabilize shorelines and provide a habitat for many species, may also be threatened. The northern Egyptian lakes, which constitute about 25% of the total Mediterranean wet lands and produce about 60% of the fish products, are also highly vulnerable to the impacts of climate change. Since the lakes are relatively shallow, climate change can lead to an increase in water temperature, which could result in changes in the lake ecosystems as well as changes in yield. So far, in-depth studies on potential impacts of climate change on lake ecosystems are not available (Agrawala et al. 2004).

It cold be summarized that Egypt's total water budget is produced by a combination of three variables: the Nile (95%), precipitation (3.5%) and ground water (1.5%). The Nile produces 55.5 billion m^3, while the latter two variables combine to form safely about 2.2 billion m^3 of fresh water. In total, Egypt has available fresh water reserves of 58 billion m^3. Egypt's annual water demand is about 77 billion m^3. The deficit between Egypt's water supply and demand must be met through recycling. The 19 billion m^3 deficit is filled by a combination of treated sewage and industrial effluent, i.e. 4 billion m^3 and recycling used water, mainly from agriculture, i.e. 8 billion m^3. An additional 4 billion m^3 is extracted from the shallow aquifer and 3 billion m^3 comes from the Al Salam Canal Project.

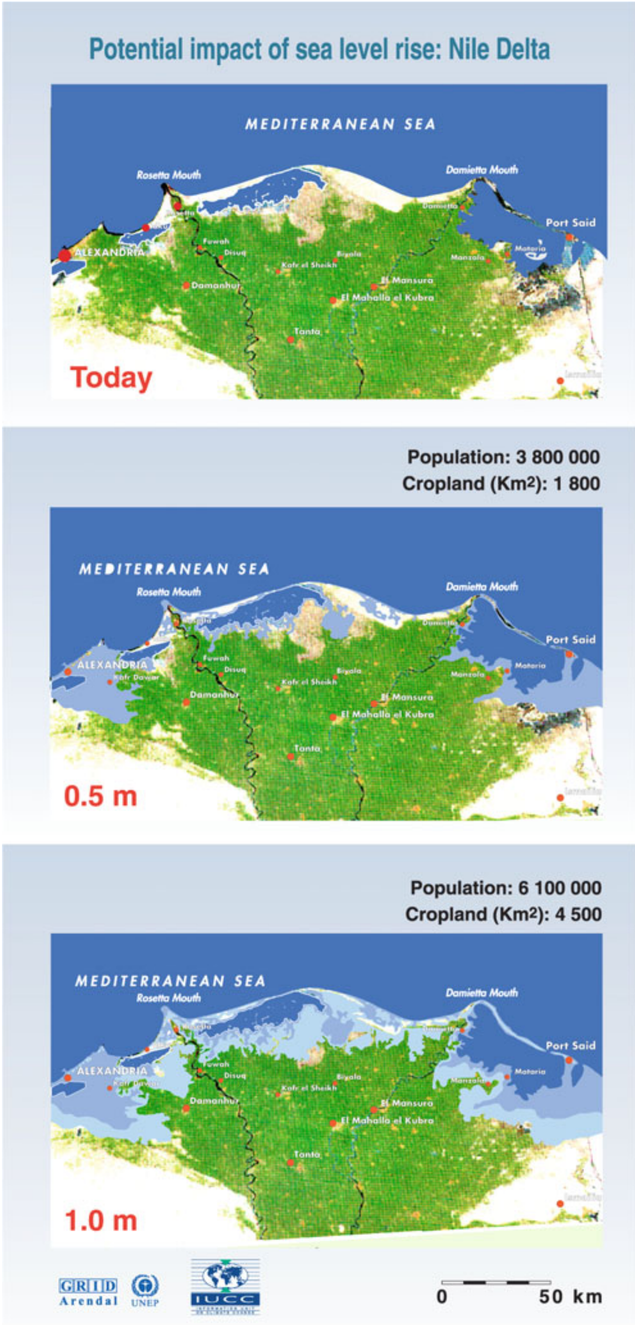
4.7 The Impacts of Sea Level Rise on Egypt

Vulnerability to climate change is considered to be high in developing countries due to social, economic, and environmental conditions that amplify susceptibility to negative impacts and contribute to low capacity to cope with and adapt to climate hazards. Moreover, projected impacts of climate change generally are more adverse for lower latitudes, where most developing countries are located, than for higher latitudes. Because of the high level of vulnerability, there is an urgent need in the developing world to understand the threats from climate change, formulate policies that will lessen the risks and to take action. The danger is greatest, where natural systems are severely degraded and human systems are failing and therefore incapable of effective response, specifically in deprived nations. Moreover, land degradation and desertification may also be exacerbated in these areas, posing additional threats to human well-being and development, added by intensified human pressures on lands and poor management. The livelihoods and food security of the rural poor are threatened by climate change with all its impacts, and the vulnerability to adverse health impacts is greater where health care systems are weak and programs for disease surveillance and prevention are lacking. In addition to multiple factors converging to make the people inhabiting coastal zones and small islands highly endangered from the causes of sea level rise. Egypt's coastal zone of the Nile delta has been defined as a vulnerable zone as a consequence of sea level rise combined with geological and human factors (El-Sharkawy et al. 2009)

It is well documented that sea level changes are caused by several natural phenomenon; the three primary contributing ones are: ocean thermal expansion, glacial melt from Greenland and Antarctica -in addition to a smaller contribution from other ice sheets- and change in terrestrial storage. Among those, ocean thermal expansion has been expected to be the dominating factor behind the rise in sea level. However, new data on rates of deglaciation in Greenland and Antarctica suggest greater significance for glacial melt, and a possible revision of the upperbound estimate for sea level rise in this century. It is predicted that, with global warming, global average sea levels may rise by between 7 and 36 cm by the 2050s, by between 9 and 69 cm by the 2080s and 30–80 cm by 2100. The majority of this change will occur due to the expansion of the warmer ocean water. Since the Greenland and Antarctic ice sheets contain enough water to raise the sea level by almost 70 m, people will be directly affected by rising sea levels in several ways. As seas rise many areas of the coasts will be submerged, with increasingly severe and frequent storms and wave damage, shoreline retreat will be accelerated. In addition to expected disastrous flooding events caused by severe climate events such as heavy flooding, high tides, windstorms in combination with higher seas (Dasgupta et al. 2007). The impacts of sea level rise will not be globally uniform, because of local variations in vertical crustal movements, topography, wave climatology, long shore currents, and storm frequencies. Low gradient coastal landforms most susceptible to inundation include deltas, estuaries, beaches and barrier islands, and coral reefs. Regions at risk include the Low Countries of Europe, eastern England, the Nile delta in Egypt, the Ganges–Brahmaputra, Irrawaddy, and Chao Phraya deltas of south-eastern Asia, eastern Sumatra, and Borneo. In the United States, the mid-Atlantic coastal plain, the Florida Everglades, and the Mississippi delta will be particularly vulnerable (Vivian 2005)

The Nile Delta is one of the oldest intensely cultivated areas on earth. It is very heavily populated, with population densities up to 1,600 inhabitants per square kilometer. The low lying, fertile floodplains are surrounded by deserts. Only 2.5% of Egypt's land area, the Nile delta and the Nile valley, is suitable for intensive agriculture. Most of a 50 km wide land strip along the coast is less than 2 m above sea-level and is protected from flooding by a 1–10 km wide coastal sand belt only, shaped by discharge of the Rosetta and Damietta branches of the Nile. Erosion of the protective sand belt is a serious problem and has accelerated since the construction of the Aswan dam (Fig. 5). Rising sea level would destroy weak parts of the sand belt, which is essential for the protection of lagoons and the low-lying reclaimed lands. The impacts would be very serious: One third of Egypt's fish catches are made in the lagoons. Sea level rise would change the water quality and affect most fresh water fish. Valuable agricultural land would be inundated. Vital, low-lying installations in Alexandria and Port Said would be threatened. Recreational tourism beach facilities would be endangered and essential groundwater would be salinated. Dykes and protective measurements would probably prevent the worst flooding up to a 50 cm sea level rise. However, it would cause serious groundwater salination and the impact of increasing wave action would be serious.

The Nile Delta is 200 km long and 255 km wide, within a coastline of over 1,000 km on the Mediterranean Sea. The low sandy coast of the Nile Delta stretches with an arc between Ras Abu Quir to the west and the Bay of Tinah, to the east.



Sources: Otto Simonett, UNEP/GRID Geneva; Prof. G. Sestini, Florence; Remote Sensing Center, Cairo; DIERCKE Weltwirtschaftsatlas.

Fig. 5 Nile Delta: Potential impact of sea level rise in 2002 and the situation for the Nile Delta when this sea level rise reaches to 0.5 m and 1.0 m. That means at 0.5 m and 1.0 m, the damage for cropland will be 1,800 and 4,500 km², respectively. At the same time the population will be displaced at rate of 3.8 and 6.1 million inhabitant, respectively. Source: Simonett (2002)**,** in: *UNEP/GRID-Arendal Maps and Graphics Library* (Retrieved 15:46, January 13, 2012 from http://maps.grida.no/go/graphic/nile_delta_potential_impact_of_sea_level_rise)

Two branches of the Nile have formed the promontories at Rosetta and Damietta. Egypt's second largest city, Alexandria is located on the northwestern part of the coastal delta zone, with a population of 3.3 million in 1996, and more than 4.1 million in 2006 (CAPMAS 2006 census).

Alexandria is the main harbor of Egypt and hosts around 40% of the country's industrial capacity, in addition to being an important summer resort and trading centre. Other large cities in the northern, low-lying delta zone include the rapidly growing city of Damietta and the historic city of Rosetta and Port Said City to the eastern side of the delta. The Nile delta region is fairly unique in the distribution of its population, topography, land-use, agricultural productivity and economic activities, which makes it extremely vulnerable to any potential impacts on its water resources and coastal zone (El Raey 2011).

The River Nile supplies 95% of the country's total water needs, including water intensive irrigated agricultural land along its banks and the delta. Agriculture is quite critical to the national economy as it employs 30% of the work force and contributes 17% to the gross domestic production (IDSC 2009). Major urban centers, commerce, and industrial activities are also confined to the narrow corridor along the Nile and the coast around its delta. The rest of the country (95%) is desert and does not support much population or economic activity. The Nile Delta region lies within the temperature zone, which is a part of the great desert belt. The average temperatures in January and July in Cairo are 12°C and 31°C, respectively. Minimum and maximum temperatures in Cairo are 3°C and 48°C, respectively. Rainfall over the Nile Delta is rare and occurs in winter. Maximum average rainfall along the Mediterranean Sea shore, where most of the rain occurs, is about 180 mm. This amount decreases very The Nile delta region is the most fertile land of Egypt which depends mainly on water that reaches the region through the River Nile with resources on the Ethiopian hills and Lake Victoria some several thousand kilometres to the south. The Nile delta coast stretches about 300 km and hosts a number of highly populated deltaic cities such as Alexandria, Port-Said, Rosetta, and Damietta. These cities are also critical centers of industrial and economic activity. In addition, the Nile delta coastal zone includes a large portion of the most fertile low land of Egypt. The topography is generally sloping from the apex at Cairo to the Mediterranean coast at a rate of about 1 m km^{-1} with varying sand dunes, ridges and low elevation areas near the coast. The coastal zone of Egypt hosts five northern lakes which constitute about 25% of the wetland of the Mediterranean and are considered main sanctuaries for birds and fish resources (El Raey 2011).

There are conflicting projections of the future availability of the water of the Nile as a result of climate change. Yates and Strzepek (1998), using a monthly water balance model, reported that five of six *global circulation models* (GCMs) showed for doubled CO_2 levels increased flows at Aswan, with increases of as much as 137% (United Kingdom Meteorological Organization). Only one *global circulation model* (GFDLT) showed a decline in annual discharge at Aswan (−15%). The variations of the results indicate that more robust studies are needed to provide a more solid base for the design of public policy. However, the more plausible projections seem to point to a reduced availability of Nile water for Egypt in the future. In addition, El Shamy et al. (2009) confirmed this strong uncertainty using 17 IPCC models.

This global sea-level rise combined with local land subsidence in many coastal areas, are expected to cause serious damage to many coastal ecosystems especially those of the low land deltaic coasts such as that of the Nile Delta in Egypt (El Raey 2011).

It could be concluded that vulnerability to climate change is considered to be high in developing countries due to social, economic, and environmental conditions that amplify susceptibility to negative impacts and contribute to low capacity to cope with and adapt to climate hazards. The sea level changes are caused by several natural phenomenon; the three primary contributing ones are: ocean thermal expansion, glacial melt from Greenland and Antarctica -in addition to a smaller contribution from other ice sheets- and change in terrestrial storage. Rising sea level would destroy weak parts of the sand belt, which is essential for the protection of lagoons and the low-lying reclaimed lands. The impacts would be very serious: One third of Egypt's fish catches are made in the lagoons. Sea level rise would change the water quality and affect most fresh water fish.

4.8 Impact of Climate Change on Crop Production in Egypt

Globally, agricultural emissions have increased by 14% from 1990 to 2005 with an average annual emission of 49 Mt CO_2 eq. yr^{-1} (US-EPA 2006). N_2O from soils and manure management and CH_4 from enteric fermentation were the agricultural sources, showing the highest increase in emissions at 21%, 18% and 12%, respectively. N_2O emissions increased by 31 Mt CO_2 yr^{-1}, which is almost twice the rate of increase for CH_4 emissions. United State Environmental Protection Agency forecasts acceleration in the global greenhouse gases emission from agriculture for the period 2005–2020. In the developing countries, the growth is expected to continue at the same rate as in 1990–2005, whereas in the more developed regions, the decreasing trend would be reversed and emission would grow by 8% up to 2020 (US-EPA 2006). Two most significant sources, N_2O from soils and CH_4 from enteric fermentation, would also increase quite rapidly. N_2O emission, which is expected to an average of 49 Mt CO_2 yr^{-1}, would continue to grow faster than CH_4 emissions, projected to an average of 35 Mt CO_2 yr^{-1} (Adhya et al. 2009).

Specific management options can be used to reduce agriculture's environmental impacts. Conservation practices, that help prevent soil erosion, may also sequester soil C and enhance CH_4 consumption. Managing N to match crop demands can reduce N_2O emission, while manipulating animal diet and manure management can reduce both CH_4 and N_2O emission from animal husbandry. Thus, all segments of agriculture have the management options which can reduce agriculture's greenhouse gases footprints. Opportunities for mitigating greenhouse gases emissions in agriculture can be grouped into three broad categories based on the following principles:

- *Reducing emissions*: The fluxes of greenhouse gases emissions can be reduced by managing more efficiently the flows of carbon and nitrogen in agricultural systems. The exact approaches, that best reduce emissions, depend on local conditions and therefore, vary from region to region.

- *Enhancing removals*: Agricultural ecosystems hold large reserves of C, mostly in soil organic matter. Any practice, that increases the photosynthetic input of C or slows the return of stored C via respiration, will increase stored C, thereby 'sequestering' C or building C 'sinks'.
- *Avoiding emissions*: Using bioenergy feed-stocks would release CO_2-C of recent origin and would, thus, avoid release of ancient C through combustion of fossil fuels. Emissions of greenhouse gases emissions can also be avoided by agricultural management practices that forestall the cultivation of new lands (Adhya et al. 2009).

Agriculture in Egypt is expected to be especially vulnerable because of hot climate. Further warming is consequently expected to reduce crop productivity. These effects are exacerbated by the fact that agriculture and agro-ecological systems are especially prominent in the economics of Egypt as one of the African countries. The rapid growth of the country's population, the economic stress of reliance on food imports, and the limited area for agriculture requires finding new ways to increase agricultural productivity in general and oil crops in specific. If climate change as projected by atmospheric scientists adversely affected crop production, Egypt would have to increase its reliance on costly food imports.

The potential impact of climate change on some field crops production and evapotranspiration in Egypt was studied through DSSAT3 and DSSAT3.5 (Tsuji et al. 1995, 1998), and COTTAM (Jackson et al. 1988) models, (El-Shaer et al. 1997; El-Marsafawy et al. 2007; El-Marsafawy 2007). Based on the mentioned previous simulation studies, climate change could decrease national production of many crops (ranging from −11% for rice to −28% for soybean) by the year of 2050 compared to their production under current conditions. Yield of cotton would be increased in comparison with current climate conditions. At the same time, water consumptive use for summer crops will be increased up to 8% for maize and up to 16% for rice by the year 2050 compared to their current water consumption (El-Marsafawy and El- Samanody 2009).

To investigate the impacts of climate change on sunflower productivity, water consumptive use, crop water productivity, farm net return and how to mitigate the potential effects of climate change on this crop, El-Marsafawy and El- Samanody (2009) studied the economic impacts of future climatic changes on sunflower crop in Egypt. They concluded that, climate change could decrease sunflower seed yield by 27%, increase water consumptive use by 12% and decrease crop water productivity accordingly by 34%. Changing sowing date of sunflower from 1st to 10th of June to 1st to 10th of May could increase seed productivity about 13–18%. Reducing irrigation water amounts by 10% could be recommended as a way to conserve irrigation water without clear reduction in seed yield. Climate change without adaptation studies could decrease farm net return about 44 and 63% for holders who own the land, and holders who rent it, respectively. At the same time, climate change could decrease the economic return from the water unit about 35%.

In brief, opportunities for mitigating greenhouse gases emissions in agriculture can be grouped into three broad categories based on reducing emissions, enhancing removals and avoiding emissions. Agriculture in Egypt is expected to be especially vulnerable because of hot climate. Further warming is consequently expected to reduce crop productivity. These effects are exacerbated by the fact that agriculture and agro-ecological systems are especially prominent in the economics of Egypt as one of the African countries. In Egypt, climate change could decrease sunflower seed yield by 27%, increase water consumptive use by 12% and decrease crop water productivity accordingly by 34%.

5 Conclusion

In the beginning of the current century, the world is facing critical global food and fuels shortages, climate change, urban growth, environmental degradation, and natural disaster-related challenges as today's world population continues to grow. Today the entire world is aware that our food supply cannot meet the demands of the world population. How can that be possible? Why can't we feed the people of the world? The answer lies in agricultural sustainable development. Agriculture is a major economic issue in Egypt. It is an issue as a local food source, for international trade, for balance of payments, land use and water use and as a basic product for food and fiber manufacturing. Hence, every aspect of the economic structure of the country relates to agriculture. For over 5000 years the farmers of Egypt created a civilization based on the union of the land and the Nile River. It was one of the earliest civilizations and it had a profound influence on the region. Agriculture created most of Egypt's wealth. Egypt, because of its very limited arable land and water resources, is probably more dependent on research to expand food production than any other country in the world. In Egypt, the search for ways to achieve sustainable agriculture and natural resource management requires changes in the traditional approach to problem solving. Researchers must cross the boundaries of their individual disciplines; they must broaden their perspective to see the merits of indigenous knowledge; and they must look to the farmer for help in defining a practical context for research. This change in vision is under way in various degrees throughout the research community, but the pace of change is slow. Two key indicators of deterioration in agricultural systems are declines in the quality of the soil and of the water. Poor management of either of these resources quickly leads to decreases in farm productivity. However the lack of any emphasis on extension of the resulting information continues to be the major problem for Egypt and the region associated with the use of the Nile waters. Egypt is subject to potential impacts of climate change, including sea level rise, inundation of the low lying lands in the Nile Delta that could reach 10–12% of the total area, impacts on water resources and agricultural productivity and associated social and economic effects. If Egypt's continued high rate of natural population increase is not reduced it could result in a population of 140 million inhabitants by 2050. This challenge calls for the need to develop a new vision for Egypt that mainly aims to deal with the potential link between climate change (including SLR, water scarcity and desertification) and human mobility (including displacement) in Egypt.

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