Chapter 2
Climate Change, Sustainability and Resilience in Egypt and Africa

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Abstract As climate change has such a broad range of effects and impacts, successful adaptation plans must consider all areas lest they unbalance effects across the range and incur hazardous effects. The UN 2030 agenda targets achieve sustainable development goals (SDGs) through integration of economic, social and environmental dimensions of development policy.

Climate resilience entails the ability of a community or system to recover rather than a tool of measurement, it should be noted that we consider ecosystem capacity in dealing with any changes while trying to retain roles in development. To improve climate resilience, policies should be applied, which focus on climate impacts and adaptation strategies from a multi-scale point of view for entirely integrated ecosystem management with consideration of interactions between industry, agriculture, trade and health.

According to the Intergovernmental Panel on Climate Change (IPCC) reports, Africa is one of the most vulnerable areas to climate change. Africa faces climate change challenges of unpredicted floods, extreme heat events, increasing aridity, reduction of rain forests and frequent droughts, which threaten community stability through agriculture productivity, water and energy security. This chapter details the application of 17 global circulation models (GCMs) with corresponding socioeconomic scenarios at a regional scale. Egypt is a water-stressed country and is facing significant vulnerabilities from climate change. Respecting the flow of the Nile

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Basin, some models predict reductions of flow, others predict increase of flow, which affects available water resources and hence agricultural and ecological services. Climate models result in contradicted outcomes, revealing complexity in potential policy management and a need for learning operational detail.

Keywords Climate change · Resilience · Adaptation · Mitigation · SDGs

2.1 Introduction

According to the UN Framework, climate change is defined as the variability in climate due to direct or indirect human activity, resulting in variation of the global atmospheric composition (Sands 1992). Climate change effects occur over decadal and century scales. The UN 2030 agenda focuses on achieving 17 sustainable development goals (SDGs) (Willis 2018). Climate hazards obstruct the achievement of the SDGs. Climate change has various impacts on water resources, agriculture, health, tourism and energy sectors. Climate hazards lead to economic losses (Abel et al. 2016). Climate change resilience can be achieved through implementation of adaptation and mitigation measures. Africa and Egypt face severe climate change; several actions and policies need to be strictly applied. Furthermore, collaborations between different countries and organisations should be performed to overcome climate change. Biophysically, different models were developed to predict the change in flow of rivers. The prediction of flow in rivers helps to understand suitable measures, which must be taken to overcome the predicted deficit in case of flow decrease and stimulate ecosystem and social productivity.

The remainder of this chapter is structured as follows: Sect. 2.2 considers the relationship between climate change and sustainable development goals; Sect. 2.3 details the effects of climate change on different sectors in Egypt and Africa; Sect. 2.4 summarises climate change impacts in Egypt; Sect. 2.5 shows economic impacts of climate change in Egypt; Sect. 2.6 discusses the prediction of the Nile flow changes resulting from climate change; Sect. 2.7 covers resilience approaches; Sect. 2.8 covers mitigation measures in Egypt and Africa. Policies and collaborations overcoming climate change in the respective regions are covered in Sect. 2.9, and the chapter concludes in Sect. 2.10.

2.2 The Relationship Between Climate Change and Sustainable Development Goals

Addressing climate change is one of the core 17 SDGs issued by the UN 2030 agenda. Figure 2.1 shows the 17 SDGs and their order. The targets of 2030 agenda can be achieved through interactions between environmental, social and economic aspects (Halkos 2015). The aforementioned interactions are necessary to combat climate hazards. The control of climate change and the application of measures able

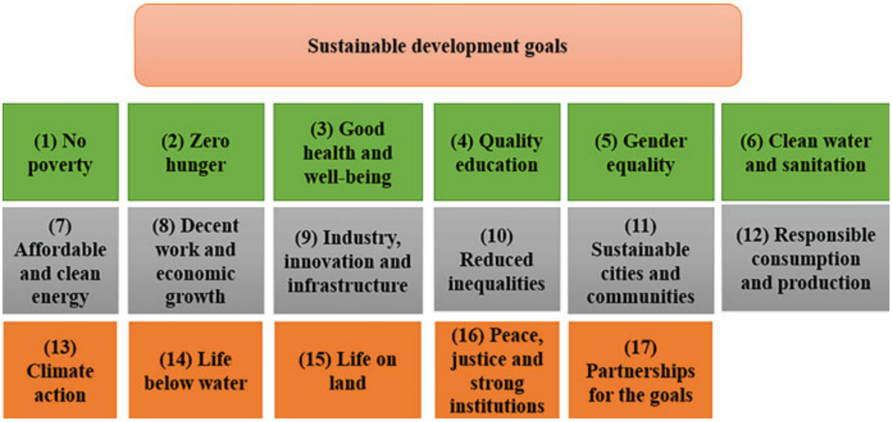

Fig. 2.1 Sustainable development goals and their order (Wilkinson et al. 2016)

to enhance resilience to climate hazards represent SDG 13 (Johnston 2016). Goal 13 also includes issuing new policies to overcome climate change and enhance awareness of mitigation measures for climate change hazards. Goal 13 has an overarching impact on the other goals. In particular, respecting goals 1–3, the increase of climate hazard frequency and intensity increases difficulties of overcoming poverty and hunger, accomplishing food security, enhancing nutrition, achieving sustainable agriculture and confirming healthy lives (SEI 2018). Climate hazards have an adverse impact on sustainability of water and energy systems (goals 6 and 7) and the safety and resilience of infrastructure, cities and human settlements (goals 9 and 11). Furthermore, continuous climate hazards prevent the sustained growth and development and increase the unemployment percentage (goal 8). All SDGs are affected by climate change.

The control of risks associated with climate change includes mitigation and adaptation measures. The effective way to face climate change hazards is via mitigation. However, several policies have responsive direction, concentrating on adaptation to overcome the detrimental consequences of climate hazards, to preserve resilience structures (IDSC 2011). Policies participate in the control of undesirable effects of climate hazards and also decrease the rate of climate change. Mitigation rather than adaptation is favoured due to the lack of available measurements of adaptation impacts compared to available metrics of mitigation measures.

2.3 Effects of Climate Change on Different Sectors

Continuous climate change leads to the rise of climate hazards through the increase of frequency, duration, extent and timing of severe weather (Lal et al. 2012). Climate change may result in human death and damage of infrastructure and resources. The damage caused by frequent climate change in countries may obstruct development for several years. Climate hazards increase poverty and inequality levels through rising health problems, the decrease of economic growth rates and by threatening food security. Disasters related to climate change are constantly increasing around the world. It has been estimated that the number of disasters per year was 323 in the 1995–2015 period, total mortality apportioned was 600,000 and the overall number of people influenced by catastrophes was 4.2 billion during the same period (Halkos 2015). Floods are the main reason for death among various disasters resulting from climate change. Water-related hazards, storms and land-related hazards such as droughts and landslides are climate hazards that may result in disruption to people's lives. Climate change hazards are not equally distributed throughout the world. Climate change has an adverse impact on different sectors (water resources, agriculture, health, tourism and energy) in Egypt and Africa.

2.3.1 Water Resources

The Nile supplies 95% of the total fresh water needs of Egypt (IDSC 2011). Egypt is a hot, arid region with a scarcity of rainfall. The rise in temperature will increase evaporation rates in equatorial and great lakes of the Nile leading to water shortage. Climate change has an adverse impact on rivers due to the increase of evaporation rate (MacDonald et al. 2012). Variation of rainfall over different regions in Africa is high (Hulme 1992). Rise in evaporation rates will also increase precipitation in Ethiopian lands resulting in the rise of run-off in the Nile River flowing downstream to Sudan and Egypt. The rise of water demand in Africa threatens water security.

Sea level rise threatens Egyptian shores. Figure 2.2 shows the sea level rise problem in Egypt. Structures that can be used to overcome sea level rise hazards in Egypt include, for example, the stone structures of the Mohamed Ali seawall, Rosetta revetment, El Agami detached breakwaters and harbour breakwaters (Koraim et al. 2011).

Fig. 2.2 Sea level rise in Alexandria, Egypt (Magdy 2019)

Sahelian regions witnessed an increase in the stream flow of rivers due to high rainfall, while there was a decrease in the stream flow of rivers in Sudanian areas due to limited rains (Amogu et al. 2010).

Ground water is a major source of fresh water in sub-Saharan Africa (Calow and MacDonald 2009). Studies report that ground water has declined by 30–70% in western areas of southern Africa and increased by 30% in eastern areas of southern Africa (Döll 2009). Uncertainties related to ground water recharge rates are high due to the lack of knowledge of ground water aquifers, though attempts are being made to rectify the paucity of information.

2.3.2 Agriculture

In Egypt, it is predicted that crop production is generally decreasing and that water demand for irrigation will increase. The prices of crops will increase, and employment chances in agriculture will decline. All scenarios predict the decline of agricultural production (Asafu-Adjaye 2014).

The IPCC reports that Africa will be negatively affected by climate change. Crop yield loss has been reported as 24% and 71% for maize and beans, respectively, due to a temperature increase of 4 °C (Thornton et al. 2011). Further the decrease of crop yields reaches greater than 50% for maize in Sahelian regions and 10–20% for other regions in sub-Saharan Africa. High-temperature conditions are not suitable for many agricultural products. Further, high temperatures suit fungal growth leading to seedling damage (Serdeczny et al. 2017). The IPCC states that countries in Africa are highly subject to climate change hazards. By 2020, 75–250 million people in Africa will have been exposed to increased water stress imposed by climate change. The percentage of arid and semi-arid areas in Africa will increase from 5% to 8% by 2080. The adaptation cost due to this increase may be 5–10% of gross domestic product (GDP) (Halkos 2015).

2.3.3 Human Health

Just as climate change alters the quality of water, air, food, soil and agricultural products, extreme climate hazards such as floods, storms and hurricanes lead to increased mortality. Higher temperatures will result in an increased mortality in Cairo (IDSC 2011). Erratic water levels and sudden climate hazards such as floods, hurricanes and storms damage homes and medical facilities and lead to migration of large portions of the population. Climate affects water quality, further increased demand leads to impure lower-quality water being used, resulting in the spread of diseases such as cholera, typhoid fever, diarrhoeal diseases and paratyphoid fever (WHO 2015).

Malaria is one of the most dangerous diseases that result from climate change (Kalkstein and Smoyer 1993). The expected number of people that will be infected by malaria will be 260–320 million by 2080. However, Egypt has had zero cases of malaria in the past three years. Malaria transfers between African countries. Recently, malaria appeared in Ethiopia, Kenya, Rwanda and Burundi, although these countries did not report the disease in previous years. The spread of cholera in Mozambique in 2000 was due to extreme weather events such as floods polluting water and food (UNECS 2013).

In Africa, floods and landslides represent a major climate hazard that leads to high mortality (McMichael and Lindgren 2011). Exposure to high temperatures for long periods also leads to death, heat stroke, fainting and heat cramps. It has been reported that there is a relationship between death and increased temperature in African countries, Ghana and Kenya (Azongo et al. 2012; Egondi et al. 2012). Droughts are related to the spread of diseases such as diarrhoea, scabies, conjunctivitis and trachoma (Patz et al. 2008).

The decline of crop yields due to climate change also affects human health due to the lack of nutritious food. An increase of temperature by 1.2–1.7°C by 2050 will increase the percentage of undernourished people to 25–90% (Lloyd et al. 2011).

2.3.4 Energy

Energy from hydropower energy supply can be influenced by climate change, as climate change affects water availability. The continuous requirement of water to cool thermal plants is also adversely impacted by climate change due to predicted water shortages. The oil refining industry consumes large amounts of water and will be affected due to water shortage arising from climate change (IDSC 2011).

African countries depend on various types of energy. For instance, Zambia, Namibia and Mozambique rely on hydropower, while other regions produce electricity using thermoelectrical sources (World Bank 2010). The change of run-off and the existence of heat streams affect the hydroelectric dams and the cooling systems for thermoelectric power plants (Förster and Lilliestam 2009).

2.3.5 Tourism

The tourism sector requires water and agricultural products and increasing demand of water and food, amidst depletion of resources due to climate change. Tourism is also affected by sea level rise, as the rise of sea level destroys offshore protective sand belts, damaging recreational activities. The decline of tourism will affect country revenue (El-Din 2013).

The number of visitors is expected to decline due to climatic hazards effecting the spread of diseases, risks to food security, damage to natural ecosystem beauty and hot conditions. The number of tourists has been seen to decrease in Morocco and Tunisia due to increased temperature. Declines in tourism activity may be due to high latitudes. The distribution of aquatic creatures is also negatively affected by climate change, and consequently tourism declines (UNEP 2012).

2.4 Summary of Climate Change Impacts in Egypt

It has been reported that climate change will have an adverse effect in Egypt by 2060. Table 2.1 summarises the predicted impacts of climate change on various sectors (Smith et al. 2013).

In Table 2.1 VSL is value of a statistical life (also in Fig. 2.3); GDP is gross domestic product; PM is particulate matter. CGCM63 is Canadian Global Climate Model, ECHAM is European Centre Hamburg Model and MIROC-M is Model for Interdisciplinary Research on Climate: three models that represent the highest increase and decrease in the Nile flow, where CGCM 63 represents the model of the highest decrease in the Nile flow, ECHAM is the model in which the variation in the Nile flow is near to the average flow in all models and MIROC-M represents the model of the highest increase in the Nile flow.

A majority of homes are considered unprotected from climate change hazards. It can be noted from Table 2.1 that precipitation will decrease due to high greenhouse gas emissions and aerosols. Moreover, the IPCC expects that Egypt will be drier and hotter.

The change in the Nile flow will be over 10% in the case of ECHAM, while the Nile flow will increase 30% in the case of MICRO-M by 2060. The Nile flow will decrease 37% in the case of CGCM63 in the same year (Smith et al. 2013).

According to Table 2.1, climate change will have a negative impact on agricultural production and employment changes. Agriculture product prices will be affected by climate change. By 2060, PM2.5 will increase, and this will lead to the death of 1000–2300 people, and the economic loss will be 0.74–2.11 billion US dollars per year. Furthermore, the rise of temperature will result in an economic loss of 5.59–6.38 billion US dollars per year in the case of tourism sector. The economic loss in housing sector in the Nile Delta region will be 0.16–0.99 billion US dollars per year by 2060 (Smith et al. 2013).

2.5 Economic Impacts of Climate Change in Egypt

Climate change has an adverse impact on different sectors in Egypt. Figure 2.3 shows the influence of climate change on the economy in 2030 and 2060. In African countries, climate change also has a severe impact on economic situations. For example, Table 2.2 shows the impacts of climate change on economic loss in Kenya.

Table 2.1 Summary of climate change impacts on different sectors in Egypt in 2060

Scenario	1	2	3	4
Socioeconomic scenario	High population; low GDP	High population; low GDP	High population; low GDP	Low population; high GDP
Nile flow scenario	Large	Small		Small
	Reduction (CGCM63)	Reduction (ECHAM)	Increase (MIROC-M)	Reduction (ECHAM)
Annual climate change in Cairo (temperature °C/% change in precipitation)	2/−10	1.9/0	2.2/−10	1.9/0
Sea level rise	High unprotected	High unprotected	High unprotected	High unprotected
Agricultural production reduction (%)	−47	−27	−8	−20
Food prices (% change)	68	41	16	32
Reduction in consumption of agriculture (%)	−30	−15	−5	−7
Welfare decline percentage (%)	−12	−6	−2	−2
Consumer surplus (% change)	−18	−11	−4	−7
Employment chances Reduction in agriculture (%)	−39	−20	3	−5
Coastal property losses (excluding agriculture; billion US $)[a]	0.45	0.45	0.45	1.01
Expected annual deaths due to air pollution (PM2.5)	1105–2308	1105–2308	1.105–2308	708–1610
Estimated economic loss due to air pollution (billion US $)	0.39–0.89	0.39–0.88	0.39–0.88	0.66–1.5
Expected annual deaths due to heat stress	2302	2187	2665	1579
Estimated economic loss due to heat stress (billion US $ using VSL)	0.88	0.84	1.02	1.47
Tourism revenues decline (billion US $)	5.25	5.25	5.25	6.38

[a]Values are estimated based on sea level rise (SLR) scenario. The annual economic losses are 0.12 and 0.15 billion US $ in the case of low- and middle-SLR scenarios depending on pessimistic socioeconomic scenario, while in the case of optimistic socioeconomic scenarios, the losses are 0.27 and 0.34 billion US $, respectively

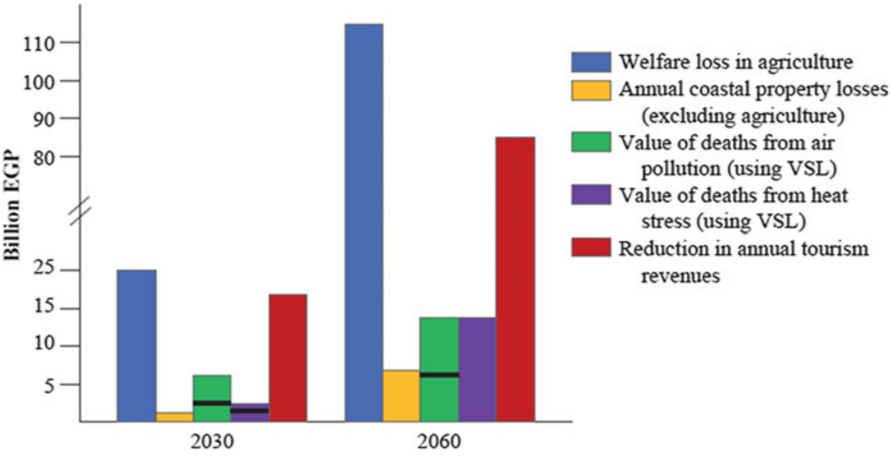

Fig. 2.3 The predicted economic loss (EGP - Egyptian Pounds) in different sectors in Egypt in 2030 and 2060 as a result of climate change (Smith et al. 2013)

Table 2.2 Impacts of climate change on economy loss in Kenya

	Import (million US $)			Needs (million US $)			
Sectors	Damage	Losses	Total	Recovery	Reconstruction	Total	DRR
Agriculture	Unknown	1191.09	1191.09	49.66	Unknown	49.66	135.11
Livestock	552.17	6326	6878.17	494.1	0.55	1046.27	837.01
Fisheries	4.94	36.01	40.95	4.0	7.41	11.41	29.42
Agro-industry	Unknown	70.42	70.42	Unknown	Unknown	Unknown	Unknown
Health	Unknown	46.68	46.68	50.15	Unknown	50.15	Unknown
Nutrition	Unknown	65.6	65.89	2.21	Unknown	2.21	1.29
Education	0.41	38.73	39.14	5.8	0.55	6.35	35.33
Energy	Unknown	318.59	318.59	127.86	Unknown	127.86	Unknown
Water and sanitation	76.09	791.42	867.5	48.82	121.01	169.84	773.32
Environment, tourism, forestry, wildlife	0.22	7.5	7.72	72.66	Unknown	72.66	6.37
Total	603.83	8892.32	9526.15	855.26	680.65	1536.41	1817.84

DRR disaster risk reduction

2.6 Prediction of Nile Flow Changes Resulting from Climate Change

Global circulation models (GCMs) were employed to investigate the influence of climate change on the flow generally in the Nile Basin and particularly in the Blue Nile sub-Basin. GCMs are global circulating models that provide 'pictures' for the

Nile Basin flow; consequently the flow of the river can be predicted. The study analysed data from 17 GCMs included in the 4th IPCC report. The modelling group of the 17 GCMs consisted of Bjerknes Centre for Climate Research, Norway (BCM); Canadian Centre for Climate Modeling and Analysis, Canada (CGCM); Canadian Centre for Climate Modeling and Analysis, Canada (CGCM63); Meteo-France/Centre National de Recherches Meteorologique, France (CNRM); CSIRO Atmospheric Research, Australia (CSIRO30); CSIRO Atmospheric Research, Australia (CSIRO35); NOAA/Geophysical Fluid Dynamics Laboratory, USA (CM20); NOAA/Geophysical Fluid Dynamics Laboratory, USA (CM21); NASA/Goddard Institute for Space Studies, USA; LASG/Institute of Atmospheric Physics, China (GOAL); Institute for Numerical Mathematics, Russia (INMCM); Center for Climate System Research, National Institute for Environmental Studies Frontier Research Center for Global Change, Japan (MIROCH); Center for Climate System Research, National Institute for Environmental Studies Frontier Research Center for Global Change, Japan (MIROCM); Max Planck Institute for Meteorology, Germany (ECHAM); Meteorological Research Institute, Japan (MRI); National Center for Atmospheric Research, USA (CCSM); and National Center for Atmospheric Research, USA (PCM). In the study, precipitation and potential evapotranspiration (PET) detailed scenarios were prepared over the Blue Nile Basin in the period 2081–2098. The Blue Nile Basin contributes 60% of the total annual flow of the Nile River. However, the uncertainties related to the climate change over the Nile Basin as well as the impacts of climate change on the Nile flow are very high.

In the period 2081–2098, Elshamy et al. (2009) reported that the sensitivity of the Blue Nile Basin to precipitation and evapotranspiration is high. Flow sensitivity resulting from potential evapotranspiration (PET) changes is mainly due to rainfall. The methods used corrected baseline climate data errors. A high reduction in rainfall may be accompanied with the increase of PET, especially during wet seasons due to the high reduction in cloud cover. Flow increases by 45% when rainfall is large enough to surpass the effect of PET rise. The majority of models showed that the flow tends to decrease. Simple relations between temperature, PET, precipitation and flow were developed. The relation between PET changes and temperature changes was linear. Flow changes can be determined using temperature and precipitation changes. All models demonstrated the rise of temperature from 2 to 5°C and stated that the rise of PET was from 2% to 14%.

A further study was made to investigate the changes in the Nile flow at Dongola (Sudan) depending on two scenarios (A2 and B2) using the data from three GCMs: CGCM2, ECHAM4 and HadCM3 (Elshamy and Sorteberg 2008). Potential evapotranspiration was estimated for the base period (1961–1990) and also for three periods in the future (2010–2039, 2040–2069 and 2070–2099); precipitation was measured for the period from 2010 to 2099. The results showed that ECHAM4 model predicted a uniform rise of the Nile flow, while CGCM2 underestimated the flow in the base period. A slight rise of flood season flow and limited increase of flow were observed in the case of HadCM3. The uncertainty of models was higher than the uncertainty imposed by the two scenarios. The uncertainty of downscaling was high and depended on the flow. Increased intensity of flood seasons may lead to larger floods in the case of ECHAM4, while droughts were expected to take place in the case of CGCM2. In the case of HadCM3, the changes of water resources in Egypt were expected to be moderate.

2.7 Climate Resilience

Climate resilience is the ability to prepare a plan to overcome the events related to climate changes (Silva-Villanueva 2019). Climate resilience helps to face problems related to extreme climate change events such as hurricanes, floods and droughts. Urban green infrastructure is considered one of the ways which can achieve climate change resilience. Urban green infrastructure overcomes human and economic losses resulting from climate change hazards such as extreme rainfall and flooding (Ibrahim et al. 2019). Furthermore, urban green infrastructure solves the problems of water accumulation in the streets due to insufficient drainage capacity. The integration between flood modelling and land use classification facilitates the choice of suitable areas to implement urban green infrastructure to counter flood and rain accumulation. Urban green infrastructure options are bioretention systems, green roofs, permeable pavements and rain barrels. In bioretention systems, the enhancement of soil infiltration and the decline of rapid run-off can be achieved by adding soil filter media and native plants to small areas. In the case of green roofs, vegetated areas can be used to collect run-off. In permeable pavements, a porous material can be used to make rainfall infiltrate into the soils. Moreover, rainfall can be collected and stored through rain barrels.

Climate change resilience can be achieved through adaptation and mitigation measures. Adaptation is defined as a group of processes and actions that participate in the management of the impacts, while mitigation refers to the overcoming of the causes of the climate change (Yohe et al. 2007). Vulnerability to climate change measures the degree of impacts of climate change. Figure 2.4 shows a framework of climate change with adaptation and mitigation.

Climate resilience requires adaptations to be made in order to mitigate the effects of change; the current section details adaptations across the sectors of Sect. 2.3, while Sect. 2.8 mentions directive mitigations for both Egypt and Africa.

2.7.1 Water Resources

The adaptation techniques in this sector should focus on reductions in water demand (Smith et al. 2013). One of the actions to relieve water demand is to charge for water; this action requires measuring water quantity to determine fees. Water scarcity problems arising from climate change may be solved by desalination, water reuse

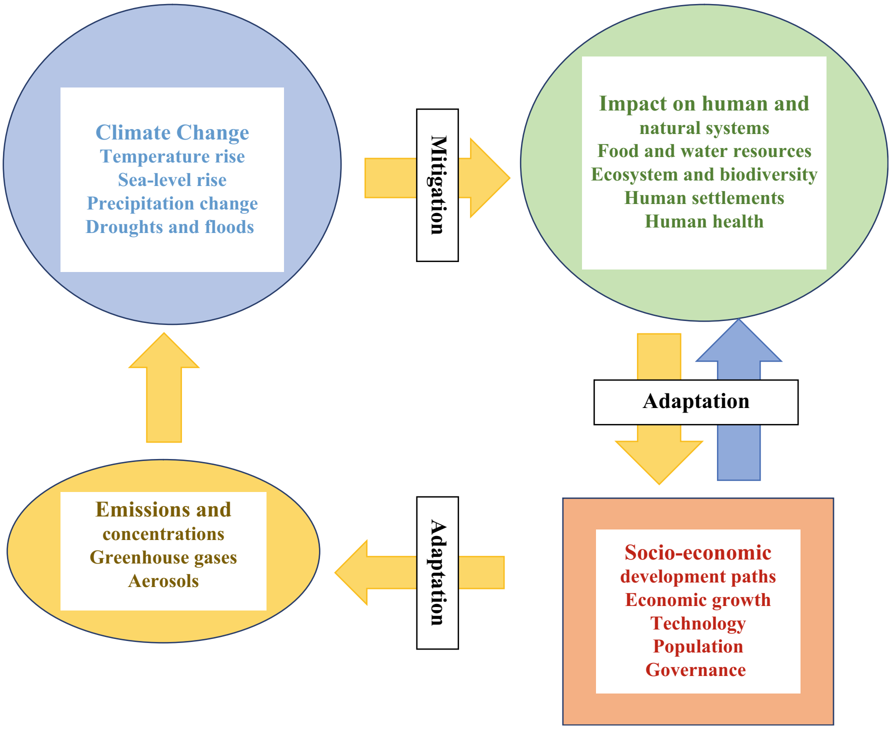

Fig. 2.4 The integrated evaluation framework of climate change with adaptation and mitigation (Vag 2009)

and ground water usage. In the case of desalination, the technology is already implemented in Egypt though needs to be expanded to deal with water shortage problems due to climate change. Conventional desalination practiced in the country requires high energy consumption, and the produced water still needs to be enhanced to be used for agriculture or drinking. Reuse is a further solution for water shortages in Egypt. The reuse of municipal and industrial wastewater reduces the demand for fresh water. Agricultural drainage water is reused at a wide scale to overcome water shortages.

In Africa, adaptation options to overcome climate change problems include increased availability of information and strict control measures on ground and surface water resources. Additionally, construction of water storage tanks can be an ideal solution to water shortage. For example, Sudan and Sierra Leone started a project to overcome climate change through rainfall catchment and storage tanks (Ministry of Environment [South Sudan] 2016).

2.7.2 Agriculture

In Egypt, modified crops and increase of agricultural imports provide major options of climate change adaptation (Attaher et al. 2009). The development of heat- and salinity-resistant crops can be achieved by genetic modification of crops, achieving growth in higher temperature and salinity conditions. Economic adaptation of a tenfold increase in agricultural imports will augment national agricultural production and additionally reduce costs.

The decrease of crop yields in Africa due to climate change will increase the number of undernourished people in Africa to 329 million in the period 2010–2100 (FAO 2014). Research in Africa focuses on the adaptation of agriculture against climate changes. For example, Chad and Cape Verde started projects for the enhancement of agricultural production, and this resulted in increased crop productivity (Ministry for Economy and Development 2010; Republic of Cape Verde – Ministry of Environment and Agriculture 2007).

2.7.3 Human Health

Air quality problems resulting from climate change should be controlled; the number of people that die due to air pollution is 20,000 per year (Sarraf 2002). Water problems arising from climate change lead to human health problems (Frumkin et al. 2011). To overcome heat stress problems, cooling centres can be an effective solution to overcome problems resulting from high temperatures (Ebi 2009).

To counter infectious diseases such as malaria resulting from climate change, surveillance systems and increased monitoring should be instigated to detect and deal with infectious disease. Health systems should be improved to overcome the outbreaks of diseases, saving costs associated with required medicines, training and communications (McMichael and Lindgren 2011). The development of regulations to overcome the spread of diseases can be a major option to overcome the problems related to climate change in African countries. For instance, Bog Togo and the Central African Republic initiated projects aimed at the prevention of diseases. These projects include the fight against malaria.

2.7.4 Energy

To overcome problems arising from climate change in the energy sector, the government in Egypt is inclined to increase the use of renewable energy such as solar/photovoltaic cells and wind power. Although targets have as yet been modestly approached, the contribution of renewable energy reached 20% by 2020 instead of 6% (Egyptian Environmental Affairs Agency 2016).

Hazards due to climate change are the increase of frequency and intensity of droughts; the increase of rainfall and extremes affects hydropower and thermoelectricity production (Förster and Lilliestam 2009). In addition to hydropower, successful application of solar and biogas projects has been made in Benin and Lesotho (UNEP 2012).

2.7.5 Tourism

To mitigate climate changes related to the tourism sector, sea level rise and variation should be considered as facilities are at risk in Egypt. Cooperation between the government and the tourism industry should be performed to overcome climate change (Egyptian Environmental Affairs Agency 2016).

Tourism creates job opportunities and increases the revenue of African countries. Due to limited information about adaptation measures in the tourism sector, a collaboration between the World Tourism Organization and UN Environment Program has been developed to check tourist destinations and evaluate tourism adaptation measures in relation to the impact of the industry and climatic change on biodiversity (UNEP 2012).

2.8 Mitigation Measures

Mitigation measures to counter climate hazards in Egypt and Africa are mentioned in the current section.

2.8.1 Mitigation Measures in Egypt

Mitigation measures that should be applied in Egypt have been proposed and documented for Egypt (Egyptian Environmental Affairs Agency 2016).

Mitigation measures include the conversion of wetlands to agricultural areas to increase the crop yield to face the rising food demand due to population increase; the development of a low-carbon strategy to mitigate greenhouse gases (GHGs); the availability of water to attract tourists, as the activities related to tourism consume considerable amounts of water with irrigation of green areas in hotels and resorts and washing of hotel towels and kitchen needs; coastal planning to protect tourism facilities from sea level rise; the increase of energy production from renewable sources especially solar energy; the promotion of sea water desalination relying on solar power using desalination technologies with high efficiency; the increased spread of natural gas use; the increased efficiency of energy delivery using new technologies; the use of efficient cars to generate fewer emissions; the implementation of policies that encourage home builders to reduce energy consumption and increase the efficiency of energy delivery; the development of new technologies that produce low emissions such as nuclear power and clean coal technology; the improvement of irrigation management systems; the construction of integrated networks for evaluation of climatic and environmental hazards; the reduction of generated waste and the improvement of livestock production systems.

2.8.2 Mitigation Measures in Africa

Examples of directive mitigation measures in Africa are as follows: increase of renewable energy use; the use of efficient means of transportation such as electric public transport and bicycles; increase in planting of trees and plants to remove greenhouse gases from air; application of fees for greenhouse gas emission; application of efficiency standards for cars and trucks; the use of photovoltaic cells, wind power, solar and geothermal and compost/biofilm systems; preservation of natural ecosystems; the preparation of flexible cultivation to overcome catastrophe; restoration of degraded lands; management of nutrients in animal and human food production to reduce emissions and the improvement of productivity through rising nutrient quality (Tubiello 2012).

2.9 Policies and Collaborations Overcoming Climate Change in Egypt and Africa

Dealing with climate change hazards cannot be achieved individually and requires cooperation between countries. It is particularly useful to share information and experience of measures that should be followed to mitigate and adapt to climate hazards. Countries issue policies and measures to protect existing investment and achieve sustainable development.

2.9.1 Egyptian Policies, Success and Opportunities

Policies have been made to overcome problems resulting from climate change in Egypt. Focus is applied to actions that achieve resilience in water resources, agriculture and food security. Policies include the improvement of livestock productivity. Moreover, adaptation strategies overcome climate hazards in several sectors (Froehlich and Al-Saidi 2017a).

Cooperation between Egypt and regional and international organisations assists in the control of climate change collectively. The matter is not limited to shared experience and information but additionally to mitigation measures.

IDSC (2011) detailed some examples of working collaborations between Egypt and other agencies as shown in the remainder of this section.

In 2010, a project was initiated to mitigate the effects of climate changes on the Nile Delta. The project was established by the cooperation between the Egyptian Ministry of Water Resources and the UN Development Programme. The objective of this project was to increase the resistance of structures facing erosion and precipitation problems. The total cost of this project was US $ 16.2 million; the project lasted for 5 years.

To overcome disasters resulting from climate change in the coastal cities of North Africa, a project was developed to save the lives of 60–90 million people by 2030. This project focuses on the prevention of climatic disasters in four cities (Alexandria, Tunis, Casablanca and Morocco's Wadi Bour Greg). The situation of these regions has to be established, and then plans need to be developed to overcome disasters according to their conditions.

A project funded by the United Nations for Food and Agricultural Organization was initiated to control the risks arising from climate change and sea level rise in the Nile Delta. This project focused on the development of decisions to mitigate and predict the climate hazards in agriculture and environments along the Delta. The project costed US $ 337.2 million and lasted for 18–24 months.

To investigate the effect of sea level rise on human movement, a project was executed by the International Organization for Mitigation and the Ministry of Manpower and Migration. The group responsible for the study includes representatives from the International Organization for Mitigation, the Ministry of Manpower and Migration, the Ministry of Water Resources, the Environment Affairs Authority, Alexandria University, Friends of the Environment Society in Alexandria and the UN International Strategy for Disaster Reduction.

2.9.2 Policies and Cooperation in Africa

To reduce climate change impacts on livestock, resources and economy in Africa, climate change measures and actions should be integrated into national decision-making. In Africa, policies are developed with overcoming greenhouse gas emissions at their core. Cooperation between African countries and global institutions are ongoing to strengthen the response towards climate change. African countries issue their policies about climate change through the African Ministerial Conference on the Environment. Further policy directives are to reduce vulnerability and disasters resulting from climate change. Cooperation between the African Union Commission, the Economic Commission for Africa, the African Development Bank, the UN Environment Programme/Regional Office for Africa and other UN bodies and development partners was developed to support the implementation of Africa's climate and development agenda.

Efforts exerted to overcome climate change in Africa are documented (Union 2010). A cooperation between African states, regional economic communities and private sector to involve climate change adaptation measures into development plans, strategies and programs at regional and national levels has to be conducted.

The construction of the African Climate Policy Centre has been achieved as a result of the decision of the African Union Conference of Ministers on the Economy and Finance and the Conference of African Ministers of Finance which provides countries' policy guidance to take required measures to overcome climate hazards. The cooperation between the African Union Commission, the African Development Bank and the Economic Commission for Africa also issued the implementation of the Climate for Development in Africa Programme depending on national, subregional and regional institutions. The objective of this programme was to promote the achievement of the Millennium Development Goals and overall sustainable development in Africa.

There are various projects initiated to overcome major climate hazards in different African countries. Table 2.3 includes projects in different African countries to combat climate hazards.

Table 2.3 Examples of projects initiated to overcome climate change in Africa (Troni et al. 2018)

Location	Project title	Project target	Average rainfall (mm/year)	Major climate hazards	Total cost (US $, in millions)
Burundi	Community risk management	Water	1700	Drought, floods	8.9
Comoros	Management of water resources	Health, food and water security, poverty reduction	7075	Droughts, floods, sea level rise and salt water intrusion, cyclones	2.85
Comoros	Improvement of the adaptive capacity and resilience in agriculture sector	Food security, poverty reduction	7075	Droughts, floods, sea level rise and salt water intrusion, cyclones	8.99
Democratic Republic of the Congo	The construction of women and children's capabilities to cope with climate change	Gender, food and water security, poverty reduction	1400	Drought, floods	4.7
Ghana	The integration of climate change into the management of priority health risks	Health	1600	Droughts, floods, heat	1.7

(continued)

Table 2.3 (continued)

Location	Project title	Project target	Average rainfall (mm/year)	Major climate hazards	Total cost (US $, in millions)
Guinea	Protection of coastal areas and communities against climate change	Food security, poverty reduction	4300	Droughts, floods, sea level rise and salt water intrusion	2.97
Eritrea	Adaptation of water and agriculture sectors towards climate change	Food and water security, poverty reduction	350	Drought, flash flooding	6.5
Ethiopia	Coping with drought and climate change	Food and water security, poverty reduction	1200	Drought	1
Kenya	Climate change adaptation in arid and semiarid lands	Food security, poverty reduction	550	Drought	1
Liberia	The improvement of resilience of vulnerable coastal areas	Coastal protection, human security	2391	Sea level rise, coastal erosion, flooding	2.9
Mali	Programme for climate change adaptation in the vulnerable regions of Mopti and Tombouctou (AF)	Food and water security, poverty reduction	1400	Drought	8.5
Malawi	Development plans for achieving adaptation to climate change	Food and water security, poverty reduction	1200	Drought, floods	4.5
Mauritius	The adaptation of coastal zone to climate change in Mauritius	Coastal protection, human security	2400	Droughts, sea level rise, coastal erosion, flooding, cyclones	8.4
Mozambique	Coping with drought and climate change	Food security, poverty reduction	800	Drought, floods	1
Namibia	Traditional crop improvement to face climate change	Food and water security, poverty reduction	450	Drought, floods	1
Niger	Scaling up community-based adaptation	Food and water security, poverty reduction	700	Drought	3.8

(continued)

Table 2.3 (continued)

Location	Project title	Project target	Average rainfall (mm/year)	Major climate hazards	Total cost (US $, in millions)
Rwanda	Construction of early warning systems to reduce vulnerability in flood-prone areas	Food and water security, poverty reduction	1400	Floods	3.84
Sao Tome and Principe	Construction of warning systems to overcome climate change	Food and water security, coastal protection	3200	Sea level rise and coastal erosion, drought, floods	3.6
Senegal	The improvement of land and ecosystem management	Gender, food and water security, poverty reduction	850	Drought	4.1
Zambia	Overcoming climate change impacts in agro-ecological zones	Food and water availability, overcoming poverty	648	Drought, pests	3.79
Zimbabwe	Coping with drought and climate change	Food and water availability, overcoming poverty	454	Drought	1
Egypt	Improvement of North Coast adaptation to climate hazards	Nile Delta low-lying land preservation	200	Sea level rise	31.4

2.10 Summary and Conclusions

In this chapter, the relation between climate change control and the achievement of SDGs was discussed. The effects of climate change on different sectors (water resources, agriculture, health, energy and tourism) were detailed in Africa and Egypt. The relationship between climate change and its force on economy was mentioned in order to show that predicted scenarios influence Egypt negatively in all sectors.

The construction of resilience stuctures is crucial to overcome climate change hazards. Climate change resilience can be achieved through the application of mitigation and adaptation measures. Moreover, urban green infrastructure can be applied to prevent floods and problems related to extreme rainfall.

The adaptation and mitigation measures were discussed for Egypt and Africa, and the framework for climate change control using adaptation and mitigation measures was explained. Examples of policies and cooperation between Egypt, African countries and regional and international organisations to overcome climate change were presented. A summary of ongoing projects initiated in different countries in Africa was shown in this chapter.

Seventeen global circulation models were used to predict the change in the Nile flow. The majority of models forecasted a decrease in the Nile flow. Three GCMs (CGCM2, ECHAM4 and HadCM3) were also used to investigate changes in the Nile flow. The results demonstrated that ECHAM4 model showed a uniform increase of the Nile flow, while CGCM2 underestimated the flow in the base period. A limited increase of seasonal flow and an overall small increase of flow were predicted in the case of HadCM3. The use of climate modelling requires the correct appreciation of the nature and weights of elements effecting change. Further research in climate mitigation should consider different metrics and structures which may be used to quantify impacts of both responsive and preventative approaches in order to stimulate populations to protect and sustain themselves into the future.

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