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Ecological Human Imprint (E_{HI}) and Water Resources in Egypt Modeling: Impacts and Assessment

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Abstract

Ecological Human Imprint (E_{HI}) is a new index that is an important measure for calculating the human demands and impacts on our global environment. In this respect, the ecological human imprint is a function of all the parameters that interact between the power of ecosystem productivity and human interactions and activities on a particular ecosystem or the demand from that ecosystem. The present paper is covering and analyzing the ecosystems' productivity and the human demand from the ecosystems. It is producing comprehensive analyses in measuring the possibility of capabilities of the ecosystems to provide goods and services to the human beings on our planet Earth. Further, the paper is discussing the models that can be used in measuring the sustainability of ecosystems and, in particular, water resources and what we should be doing to maintain healthy ecosystems in Egypt.

In this respect, the paper has assessed and introduced a comprehensive model called Ecological Human Imprint (E_{HI}) and water resources change of Egypt (EHI-WR-EG) that can describe the status of our ecosystems' productivity and the impacts of changing of water resources on the availability and human population within the Egyptian boundaries. Furthermore, the paper has provided some answers to the human issues in Egypt. Water resources change impacts as the results of human activities. Additionally, the model has provided a warning to the current trend in use and abuse of our natural ecosystems. Furthermore, provides a prediction on what will be expected from these ecosystems to provide the human needs in response to the current use of Egypt's ecosystems.

Keywords: *Ecological Human Imprint, Egypt, ecosystems*

Introduction

Egypt is one of the most populace nations, and over the last fifty years, the population of Egypt has more than tripled (The World Fact Book-https://www.cia.gov/library/publications/the-world-factbook/geos/eg.html 2014). The water resource is one of the most important factors for economic development. The water demand has multiplied as a result of population growth, agricultural expansion, and industrial development as well as increases in the standard of living. Water for the land is provided by the River Nile. In this respect, Egypt relies heavily upon the River Nile, which forms more than 95% of the national water budget (Shahin 1985). Only a very small amount of precipitation falls near the Mediterranean Sea, and the intensity of the rain varies spatially and temporally. There is an additional existing ground water in Egypt (i.e.

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shallow aquifers associated with irrigation in the Nile valley and Delta and reservoirs are existed in the coastal strip as freshwater). Groundwater can also be found in the Western Desert, Eastern Desert, and Sinai Peninsula.

The Nile Basin covers roughly 2.9 million km^2, which is almost 10% of the size of the African continent which is about (30.2 million km^2) (Gleick 1991, https://en.wikipedia.org/wiki/Africa, accessed on July 5, 2015). The River Nile flows north for a distance of 6500 km 4^o S to 31^o N latitude and extends from 21^o $30^{'}$ to 40^o $30^{'}$ E longitude. The Nile and its tributaries (White Nile, Blue Nile) flow through nine countries: Tanzania, Uganda, Rwanda, Burundi, Zaire, Kenya, Ethiopia, Sudan, and Egypt (Shahin, 1985). However, the Nile Basin flows through ten countries since the establishment of North and South Sudan as two separate countries.

Accordingly, Egypt has reached a state where the quantity of water available is imposing limits on its national economic development. The threshold value of 1000 m^3/capita/year is often used as an indication of scarcity in absolute terms (*MWRI-EGYPT, 2014)*). Egypt has passed that threshold already in the years of the 1990s. As a threshold of absolute scarcity, 500m^3/capita/ year is used. This will be evident from population predictions for 2025, which will bring Egypt down to 500 m^3 / capita / yr.

The objective of this study is to assess and evaluate the impacts of ecological human imprint (E_{HI}) on the resources of Egypt and to propose a model for predictions and scenarios of what will be happening in the next 50 and 100 years and the prospective impacts of growing human populations in Egypt. Furthermore, the study develops an analytical study of the future. Further, this study will support the decision maker with the tool that can help to take the right decision to avoid the disastrous situation in Egypt.

Importance of Water Resources in Egypt

The water resources in Egypt are very scarce. This is due to the lack of rain, which is less than 200 mm / year in the northern part of Egypt along the Mediterranean Sea. Inland the rainfall is more scarce. The only water available to the Egyptian people is the River Nile Basin. Of these water resources, 80-85% are used for agriculture. Industry and other usage accounts for 7% -7.5% of water usage. The following is the usage or withdrawal of water resources of Egypt: 1) actual primary resource: 58.3 billion m^3/year, (groundwater, and surface water, internal and external), 2) secondary resources: 8.1-9.0 billion m^3/year, a) infiltration of irrigation water to groundwater: 4.0 km3/year drainage water and b) conveyance losses returned to the Nile River 4.1 billion m^3/year, and the total exploitable water resource is 66 billion m^3/year (of which withdrawals of the groundwater amount to 5.3 billion m^3/year-plus reuse) (Amer, 1999). If we compare the actual Total Renewable Water Resources (TRWR) (58.3 billion m^3 / year) with the actual water withdrawal (i.e., 66 billion m^3 / year), it would indicate overexploitation. However, it is not the case here because return flow and infiltration from agricultural fields (secondary resources) represent significant elements in the country's water balance. Table (1) summarizes the water resources in Egypt. This includes the water resources' availability and water usage in Egypt.

Materials and Methods

1. Water Footprints Data Collection

Water footprint data used in this study were collected from different data sets of series available on the web sites of the World Research Institute (WRI)-Earth-Trends (1960-2010), World Bank, UN Food and Agricultural Organization (FAO).

2. Water Footprint Accounting

Hoekstra et al., 2011 and Ercin et al., 2013 indicated that water footprint (WF) has three components: green, blue, and grey water. The blue water footprint refers to consumption of blue water resources (surface and ground water). The green water footprint is the volume of green water (rainwater) consumed, which is particularly relevant in crop production. The grey water footprint is an indicator of the degree of freshwater pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards. The water footprint of national production is the total freshwater volume consumed or polluted within the territory of the

nation. This includes water used for making products consumed domestically but also water used for making export products. It is different from the "water footprint of national consumption," which refers to the total amount of water that is used to produce the goods and services consumed by the inhabitants of the nation. This refers to both water use within the nation and water use outside the territory to the nation, but is restricted to the water use behind the products consumed within the nation. The water footprint of national consumption thus includes an internal and external component. The internal water footprint of national consumption is defined as the use of domestic water resources to produce goods and services consumed by the national population.

Table 1

Water Resources Availability and Water Usage in Egypt

Water Resources	Volume in BCM*	%
Nile Water	55.5	76.6
Groundwater Extraction	6.10	8.4
Non-Conventional Sources	9.0	12.4
Desalinization	0.3	0.4
Rain	1.14	1.6
Total	72.04	100

Water Usage	Volume in BCM*	%
Agriculture Demand	57.8	80
Industrial Demands	7.5	13.3
Municipal Water Usage	4.7	6.4
Navigation	2.1	2.9
Other Usage	0.4	0.55
Total	72.5	100

Source: MWRI-2002 Ministry of Water Resources and Irrigation of Egypt
*BCM Billion Cubic Meter

*Non-conventional sources and includes; the renewable groundwater aquifer underlying the Nile Valley and Delta, the reuse of agricultural drainage water, and the reuse of treated sewage water. These sources are recycling processes of the previously used Nile fresh water in such a way that improves the overall efficiency of the water distribution system

Therefore; the internal water footprint is the sum of the water footprint within the nation minus the volume of virtual-water export to other nations (i.e. as related to the exports of products produced with domestic water resources).

The external water footprint of national consumption is defined as the volume of water resources used in other nations to produce goods and services consumed by the population in the nation considered. It is equal to the virtual-water import into the nation minus the volume of virtual-water export to other nations because of re-export of imported products.

The water footprint of crops and derived crop products produced in Egypt was obtained from Mekonnen and Hoekstra (2010a, 2010b, 2011a, 2011 b) who estimated the Egyptian water footprint of crop production with a crop water use model at a 5 by 5 arc minute spatial resolution. The water footprint of animal products that are produced in Egypt was taken from Mekonnen and Hoekstra (2010b, 2012). The data related to the water footprint of production and consumption in Egypt and the virtual water flows to and from Egypt were taken from Mekonnen and Hoekstra (2011b). In all cases, data refer to the period 1996–2005. Additionally, some of the data was collected for years from 1960-2010 in an annual series.

3. Water Footprint Calculations for Egypt

Table (2) showed the sources of the water footprint in Egypt and is divided into the green water footprint, equal to 11856 million m^3 per year, blue water footprint, equal to 34447 million m^3 per year, and grey water footprint, equal to 22421 million m^3 per year. The total water footprint in Egypt is 68724 million m^3 per year. The distribution of the water footprint of Egypt is translated to 17.3% green water, 50.1% blue water, and 32.6% grey water. However, if we calculate the per-capita water footprint, we find that the water footprint is declining each year due to continuous increase of the human population at an alarming rate. In this respect, the published data from the Egyptian government and other world resources data showed the growth rate of the Egyptian population will increase to 2.01% annually through the trend from year 1960-2012. Figure 1 shows the distribution of the water footprint in Egypt according to different categories (blue, grey, and green footprint per capita).

Table 2

Sources of Water Footprint in Egypt as Classified by Green, Blue, and Grey water in Million Cubic Meter / Year*

Water Footprint of	Green	Blue	Grey
Crop Production	7319	33517	13851
Grazing	4537		
Animal Water Supply		200	
Industrial Production		200	3800
Domestic Water Supply		530	477
Total Water Footprint	11856	34447	22421

*Source of the Data: UNESCO IHE Institute of Water Education - M.M. Mekonnen, A.Y. Hoekstra May 2011- National Footprint Accounts: The Green, Blue and Grey Water Footprint of Production and Consumption Vol. 2: Appendices Research Report Series No. 50 – value of Water.

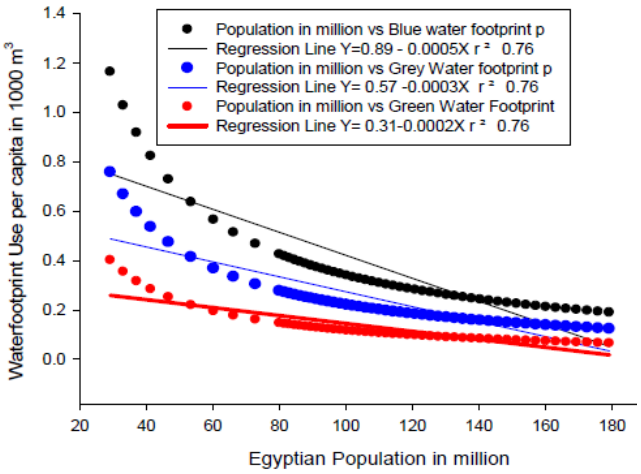


Figure 1: Relationship between human population and water footprint categories (i.e. blue, gray, and green water footprint) per capita

This graph indicates that the use of water resources per capita is decreasing. Therefore; the graph indicates the scarcity of water and how this scarcity of water will impact the need for water resources to satisfy the needs of the human population in Egypt.

Consequently, this will impact the development and the sustainability for the country. In addition to the rapid deterioration, which is occurring in surface and groundwater quality, another factor that may affect the water use in Egypt is climate change affects the rainfall in the River Nile Basin, which impacts the whole basin, including the other countries who share the water resources of the Nile. These changes will severely impact Egypt, as a country of the downstream. Furthermore, the climate change will affect the upper stream countries that are competing for Nile's water resources, such as Ethiopia and is currently building a new dam which is called "Al Nahda Dam.". Currently, the African countries are trying to change the Nile Basin treaty of 1929 to reduce the share of water resources for Egypt. In this respect, the River Nile Basin is fluctuating for its water resources due to the changing in the rainfall annually as the result of climate change.

In this respect, the actual resources currently available for use in Egypt are 55.5 Billion Cubic Meter / Year, 1.3 Billion Cubic Meter / year effective rainfall on the northern strip of the Delta, and non-renewable groundwater for western desert and Sinai. However, the water requirements for different sectors are in the order of 79.5 Billion Cubic Meter/ year. The gap between the needs and availability of water is in the range of 20 to 24 Billion Cubic Meter/yr. and may be more. This gap can be overcome by recycling and other technological advances in conserving water resources. The overall efficiency of the Nile system in Egypt is about 75% (Ministry of Water Resources and Irrigation - Egypt, 2014). According to FAO reports, the general pattern of rainfall over the Nile Basin shows high rainfall in the mountainous areas in the south and east, typically about 2000 mm per year, and even more in certain locations. In the plateau areas of the southern lakes' region, it is generally in the range 1000-1500 mm. However, northwards through southern Sudan, rainfall gradually declines, reaching about 200 mm per year at the junction of the Blue and White Niles in Khartoum. North from there, desert conditions prevail and rainfall drops to practically zero in northern Sudan and most of Egypt. This marks a progression from humid climates that can support the rainforest to a range of less humid and semi-arid climates, where the vegetation is a variety of types of savannah and grassland, to arid climates in the north, supporting practically no vegetation.

4. Modeling Ecological Human Imprint (E_{HI}) and Water Resources Change of Egypt (EHI-WR-EG)

Description of the Model

The Ecological Human Imprint and Water Resources Change of Egypt (EHI-WR_EG) model is designed to predict the impact of human consumption of water resources in Egypt and the impacts of water scarcity in the future sustainability of water on Egypt's development, food security, and in consequence, the national security (i.e. the model will be a tool to measure the changes in the parameters that will have an impact on the water resources for continuation and sustainability of development). This will include the agro-ecosystems to regenerate biocapacities to support the Egyptian lands to supporting the Egyptian human population to supporting the development and sustainability of the country. This model is written using the STELLA modeling software package (2001) version number 8.0. The model used annual, and other time periods (i.e. the model can run with different time periods such as a year, every five years, and every ten years) using the fourth Runge–Kutta integration method (Ouyang, 2008). The most important parameters that were used in the model are: 1) Egypt's human population (EGHUP), 2) green water footprint (GW), 3) blue water footprint (BW), 4) grey water footprint (GRW), 5) water maintenance index (WMI), 6) water deficit in m^3, 6) decline water (DW) in $m^{3,}$ 7) consumed water in billion m^3, and 8) net water resources per capita (NWR) in m^3.

The EHI-WR-EG model predicts the condition of the water sustainability of Egypt and predicts the needs for water from the Egyptian territories from year 1960 to year 2050. However, the model can predict the perspectives for other time periods. Therefore; the simulation period could be from one year to several years and could be used for a short time period of simulation. Background data and literature parameters were used to initialize the model and short-term data collected from different sources and data sets of series are available on the web sites of the World Research Institute (WRI)-Earth-Trends, World Bank, Food and Agricultural Organization (FAO), United States Department of Agriculture (USDA), United Nation Development Program (UNDP), World Wildlife Fund (WWF), and Global Water Footprint. Table (3) shows the list of variables and parameters in the model and its interpretation.

Table 3

EHI-WR-EG Model Parameters and Description

E_{HI}	Ecological Human Imprint – Index for calculating the impact of humans on water resources
Green Water Footprint (GW)	GW is the volume of green water (rainwater) consumed, which is particularly relevant in crop production
Grey Water Footprint (GRW)	GRW is an indicator of the degree of freshwater pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards
Blue Water Footprint (BW)	BW is consumption of surface and ground water in m^3 per capita
Egyptian Population	EGHUP Egyptian population in millions
WMI	Water Maintenance Index as % of water availability
WDC	Water Deficit in m^3 per capita
DW	Declining Water in m^3
CW	Consumed Water in in Billion Cubic Meter
NWR	Net Water Resources per Capita in m^3

Results

A. Ecological Human Imprint and Water Resources in Egypt

Figures 2-7 indicate the status of Egyptian water resources. From these figures, we can extract the following facts: 1) The relationship between the population and actual total renewable water resources and the exploitable water resources per capita is declining. This indicates the scarcity of water resources available to the human population of Egypt. 2) This decline will cause a reduction in the possibility of recovering and renewing water for the production of crops and other agricultural products, which can be a threat to the food security of Egypt. 3) Figure 2 indicates the deficit of the water resources in Egypt by approximately 0.6 thousand cubic meters when the population has reached 172-180

million people and in the year 2050; 4) Figure 3 indicates that the maintenance index of water supply in Egypt is in a decline mode; 5) The availability of ground water resources per capita is declining from 50 m^3 for the population of 20 million people (during 1961) to below 10 m^3 when the population of Egypt reaches 150 million people and more (Figure 4); and 6) Figure 5 shows that the human population in Egypt is increasing to the level that the renewability of water resources is declining, and water scarcity will be imminent by the year 2040.

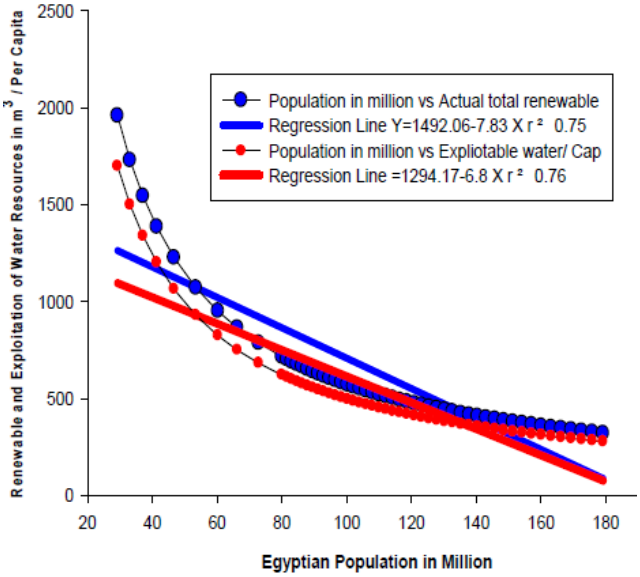


Figure 2: Relationship between Egyptian population and actual total renewable and total exploitation of water per capita

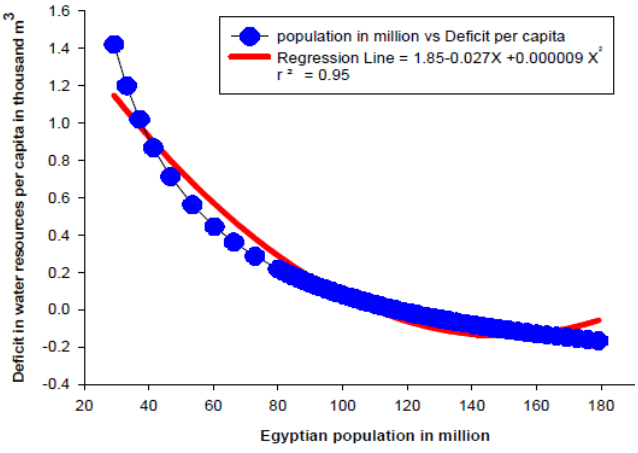


Figure 3: Relationship between Egyptian population and deficit of water resources per capita

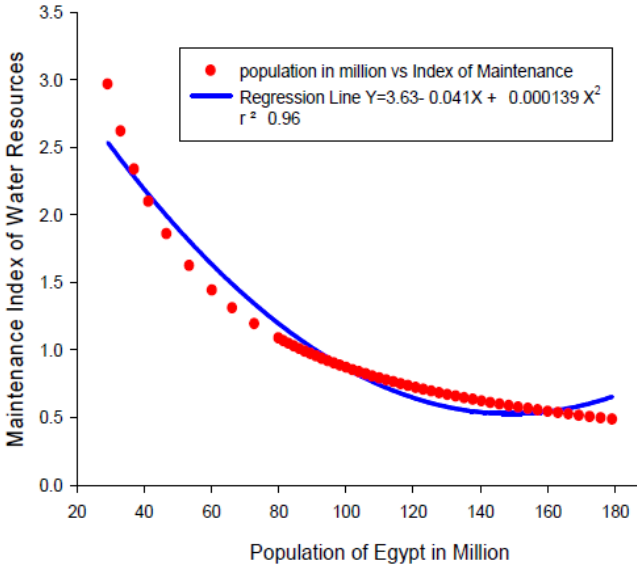


Figure 4: Relationship between Egyptian population and Water maintenance Index (WMI) per capita

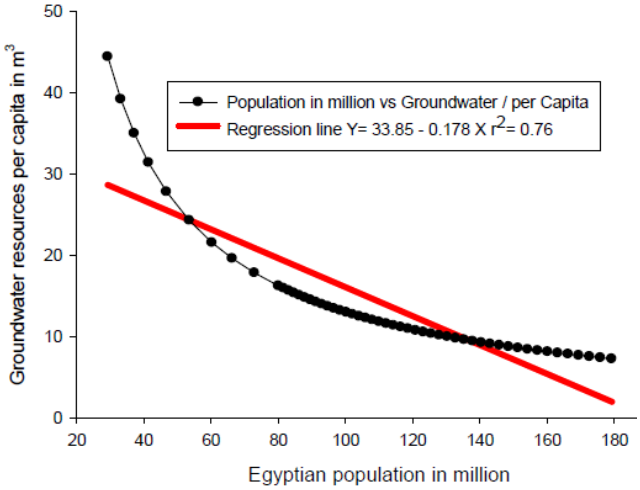


Figure 5: Relationship between Egyptian population and groundwater availability per capita

Furthermore, Figure 6 indicates that the alarming increase in the Egyptian population by year 2050 accompanied by the increasing water deficit will result in a shortage of water supplies so great that it will impact the whole society with increasing demands for water resources and food production for the food security of the people (Figure 7). It is essential that Egypt maintains food security in order to avoid the consequences of the shortage of water supplies, famine, production of goods and services; and increasing unemployment, destruction of the environment, and injustices.

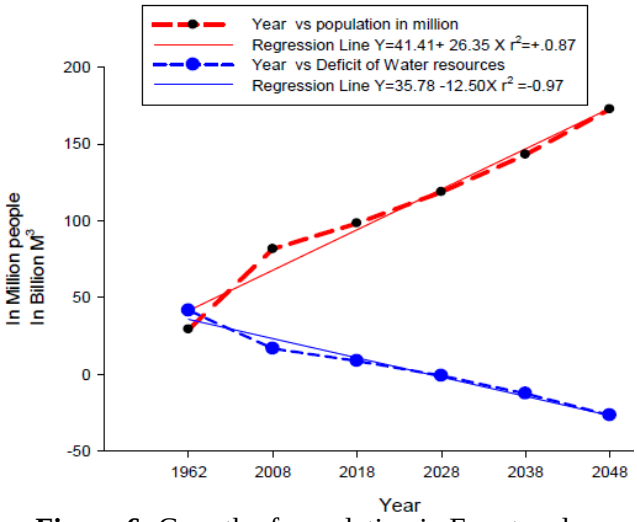


Figure 6: Growth of population in Egypt and water deficit or scarcity

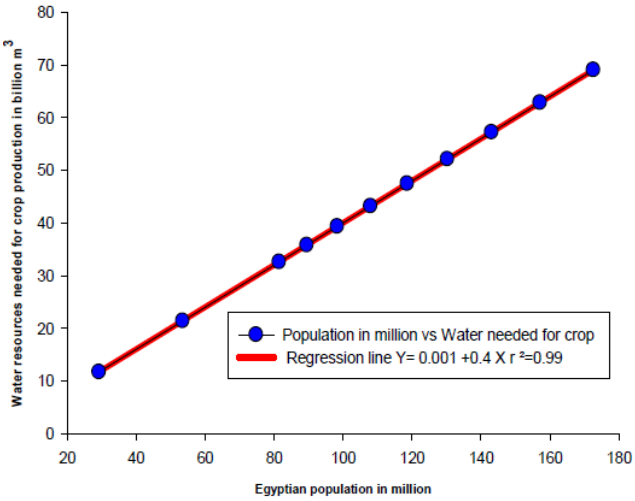


Figure 7: Relationship between Egyptian population and water resources needed for crop production

These are the main factors that can cause disturbance in the society and result in instability.

B. EHI-ER_EG Model Formulas, Simulation, and Analysis

Model Formulas

The following are the formulas used in the model to predict what will happen beyond the available data.

1. The relationship between the Egyptian population and actual renewable water resources per capita is Y= 1492.06 – 7.83 *population.
2. The relationship between the Egyptian population and actual exploitable water resources per capita is Y=1294.17 – 6.8 *population.
3. The relationship between the Egyptian population and the deficit of water resources per capita is 1000 m^2 is Y= 1.85-0.027*population + 0.000009 *population*population
4. The relationship between the Egyptian human population and water maintenance index (WMI) is Y= 2.258 – 0.0117 *population.
5. The relationship between the Egyptian population and ground water availability is Y=33.85 – 0.178* population.
6. The relationship between years and water deficit and scarcity is Y= 35.79-12.50* years.
7. The relationship between years and the Egyptian population is Y=41.41 + 26.35 *year.
8. The relationship between the Egyptian population and water resources needed for crop production is 0.0001+0.4*population.

Model Simulation and Analysis

According to the proposed EHI-WR_EG model simulation analysis output (Tables 4-9 and Figures 8-10) showed that there is a trend in increasing population of Egypt during 1960-2050 and the decreasing maintenance water index (MWI %) to express the concern over scarcity of water availability for development and sustainability to Egypt's population. As Figure 8 shows, the simulation model indicates that the E_{HI} of Egypt is reaching an alarming rate and the exploitation of water resources is an imminent. This will impact the production of food, especially wheat, which is the major source of feeding the Egyptian people. According to the model, the human population in Egypt will reach 53 million at the 1% growth rate and 175 million people at the 2% rate by the year 2050. Therefore, these predictions are dependent on the other parameters, such as the availability of water resources and human growth rates.

Table 4

Egyptian Population, Egyptian Water Resources (EGWR), Egyptian Water consumed, and Egyptian Water Maintenance Index (WMI) from Year 1962 to Year 2010 - Data is in 10 year intervals as predicted by Growth Population of Egypt in 1%*

Year	Population in Million People	Net Water Resources Per Capita	Water Maintenance Index (WMI)	Total Consumed Water In Billion m^3	Blue Water / Capita in m^3	Green Water / Capita in m^3	Grey Water / Capita m^3
1962	29.70	1258.45	2.26	37.58	0.75	0.26	0.49
1970	32.17	1241.08	2.18	40.14	0.74	0.25	0.48
1980	35.56	1214.59	2.07	43.44	0.72	0.25	0.47
1990	39.30	1185.30	1.96	46.89	0.70	0.24	0.46
2000	43.43	1152.94	1.84	50.48	0.68	0.24	0.45
2010	48.00	1117.18	1.71	54.09	0.66	0.22	0.43

* Data Sources are World Bank- FAO – WWF – Ecological Footprint Network – WRI-Earth Trends - US Estimates, Ministry of Water Resources and Irrigation- Egypt (MWRI-EGYPT).

Table 5

Egyptian Population, Egyptian Water Resources (EGWR), Egyptian Water consumed, and Egyptian Water Maintenance Index (WMI) from Year 2020 to Year 2050 - Data is in 10 year intervals as predicted by Growth Population of Egypt in 1%*

Year	Population in Million People	Net Water Resources Per Capita	Water Maintenance Index (WMI)	Total Consumed Water In Billion m^3	Blue Water / Capita in m^3	Green Water / Capita in m^3	Grey Water / Capita m^3
2020	53.05	1077.65	1.57	57.73	0.64	0.22	0.42
2030	58.62	1033.97	1.42	61.31	0.61	0.21	0.40
2040	64.79	985.70	1.27	64.71	0.59	0.20	0.38
2050	71.60	932.34	1.12	67.79	0.55	0.19	0.36

* These values are from the model prediction

Table 6

Egyptian Population, Egyptian Water Resources (EGWR), Egyptian Water consumed, and Egyptian Water Maintenance Index (WMI) from Year 1961 to Year 2008 - Data is in 10 year intervals as predicted by Growth Population of Egypt in 1.7%* (i.e. is the current Growth Rate)

Year	Population in Million People	Net Water Resources Per Capita	Water Maintenance Index (WMI)	Total Consumed Water In Billion m^3	Blue Water / Capita in m^3	Green Water / Capita in m^3	Grey Water / Capita m^3
1962	29.70	1258.46	2.26	37.58	0.75	0.26	0.49
1970	34.03	1226.57	2.12	41.97	0.73	0.25	0.47
1980	40.33	1177.20	1.93	47.81	0.70	0.24	0.45
1990	47.81	1118.68	1.71	53.94	0.66	0.23	0.43
2000	65.66	1049.32	1.47	60.10	0.62	0.22	0.41
2010	67.16	907.10	1.22	65.86	0.57	0.20	0.32

* Data Sources are World Bank- FAO – WWF – Ecological Footprint Network – WRI-Earth Trends - US Estimates, Ministry of Water Resources and Irrigation- Egypt (MWRI-EGYPT).

Table 7

Egyptian Population, Egyptian Water Resources (EGWR), Egyptian Water consumed, and Egyptian Water Maintenance Index (WMI) from Year 2020 to Year 2050 - Data is in 10 year intervals as predicted by Growth Population of Egypt in 1.7%*

Year	Population in Million People	Net Water Resources Per Capita	Water Maintenance Index (WMI)	Total Consumed Water In Billion m^3	Blue Water / Capita in m^3	Green Water / Capita in m^3	Grey Water / Capita m^3
2020	94.74	869.65	0.96	70.51	0.52	0.18	0.34
2030	115.72	754.14	0.70	72.95	0.45	0.15	0.29
2040	141.34	617.22	0.48	71.54	0.37	0.13	0.24
2050	172.63	454.94	0.31	63.84	0.27	0.09	0.18

* These values are from the model prediction

Table 8

Egyptian Population, Egyptian Water Resources (EGWR), Egyptian Water consumed, and Egyptian Water Maintenance Index (WMI) from Year 1961 to Year 2008 - Data is in 10 year intervals as predicted by Growth Population of Egypt in 2%* (i.e. is the current Growth Rate)

Year	Population in Million People	Net Water Resources Per Capita	Water Maintenance Index (WMI)	Total Consumed Water In Billion m^3	Blue Water / Capita in m^3	Green Water / Capita in m^3	Grey Water / Capita m^3
1962	29.70	1258.46	2.26	37.58	0.75	0.26	0.49
1970	34.85	1220.10	2.10	42.77	0.72	0.25	0.47
1980	42.67	1159.68	1.86	49.73	0.69	0.24	0.45
1990	51.99	1085.88	1.60	57.00	0.64	0.22	0.42
2000	63.51	996.74	1.30	64.05	0.59	0.20	0.38
2010	77.57	885.65	1.00	69.91	0.53	0.18	0.34

* Data Sources are World Bank- FAO – WWF – Ecological Footprint Network – WRI-Earth Trends - US Estimates, Ministry of Water Resources and Irrigation- Egypt (MWRI-EGYPT).

Table 9

Egyptian Population, Egyptian Water Resources (EGWR), Egyptian Water consumed, and Egyptian Water Maintenance Index (WMI) from Year 2020 to Year 2050 - Data is in 10 year intervals as predicted by Growth Population of Egypt in 2%*

Year	Population in Million People	Net Water Resources Per Capita	Water Maintenance Index (WMI)	Total Consumed Water In Billion m^3	Blue Water / Capita in m^3	Green Water / Capita in m^3	Grey Water / Capita m^3
2020	94.74	751.18	0.70	72.97	0.45	0.15	0.29
2030	115.72	589.94	0.44	70.60	0.35	0.12	0.23
2040	141.34	286.33	0.34	68.61	0.23	0.08	0.15
2050	172.63	141.31	0.28	76.90	0.13	0.03	0.05

* These values are from the model prediction

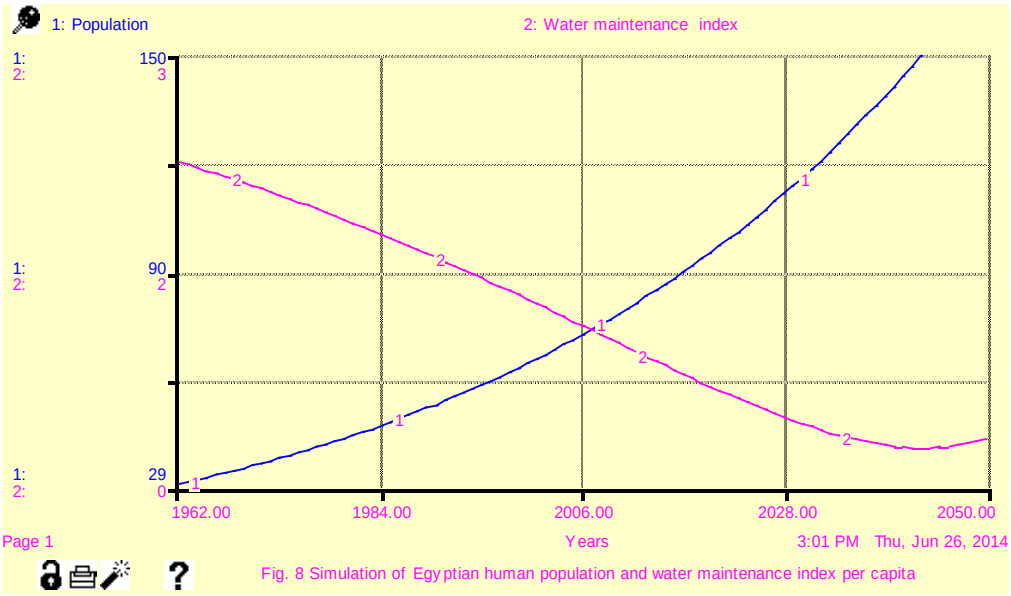


Figure 8: Simulation model for Egyptian human population and water maintenance index (WMI %) (i.e. at the 2% annual growth rate)

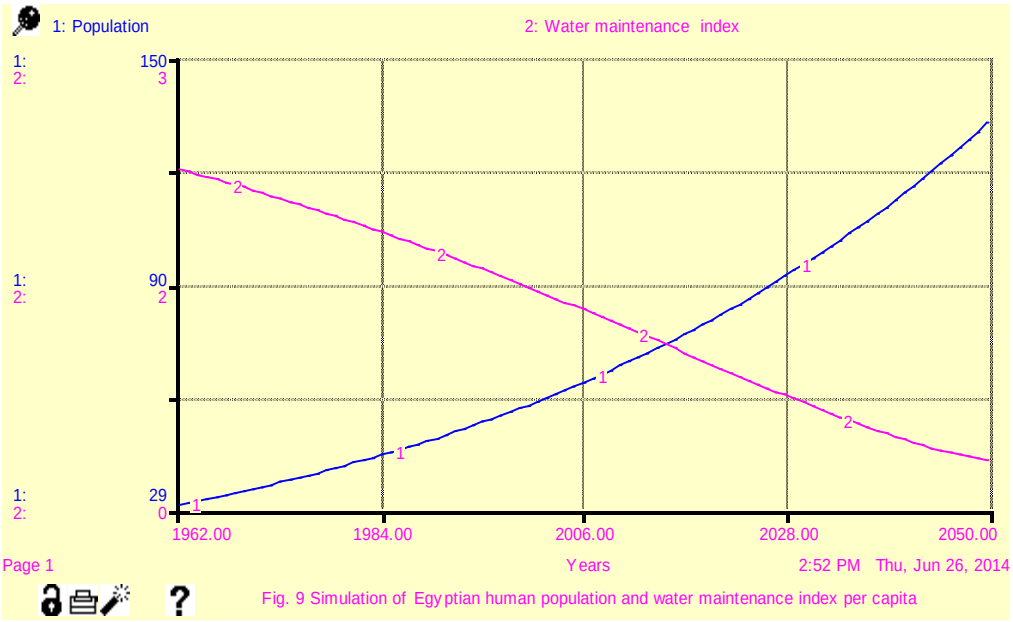


Figure 9: Simulation model for Egyptian human population and water maintenance index (WMI %) (i.e. at the 1.7% annual growth rate)

These results also indicate that the water maintenance index is at the breakeven point at year 2010 when the growth rate is around 2%. However, these results are at the breakeven point at year 2030 when the growth rate is around 1% (i.e. availability and consumption of water resources are equal to human population). This means that the human growth rate can be of an effect on water resources' availability and scarcity, and the extension of the breakeven point is extended to more than 20 years to help support the demands of water supply.

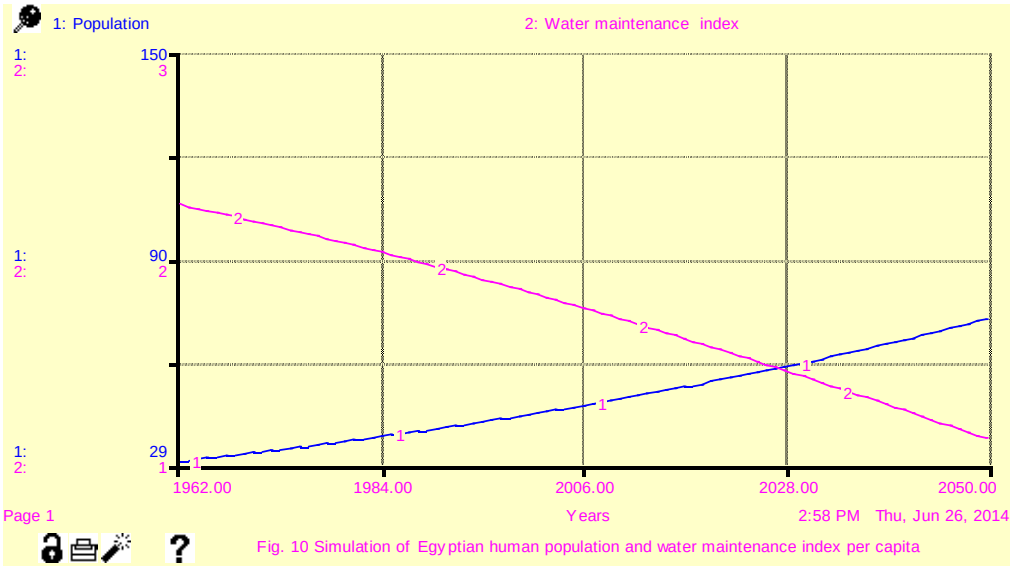


Figure 10: Simulation model for Egyptian human population and water maintenance index (WMI %) (i.e. At the 1% annual growth rate)

The model EHI-WR-EG can explain the impact of the increasing growth rate of the Egyptian population on the different categories of the water footprint (green, grey, and blue) and the decline of water resources. Additionally, Figures 11-13 show that the increasing human population can cause the increasing scarcity of water resource availability, which will impact the whole society. The model also indicates that the higher population growth rate will result in greater consumption of useful water. This will result in the deterioration of water resources for the country.

C. Consequences of Usage of Water Resources, Water Scarcity, and Sustainability in Egypt

The growth of Egypt's population is reaching an alarming rate and has increased by more than 40% since the early 1990s. This means that every week, 27,000 newborns are added to the population, and future projections say that the population will grow from its current total of 81.6 million to 101.6 million by the year 2025. The rapid population increase multiplies the stress on Egypt's water supply requiring more water requirements for domestic consumption, increased irrigation water use to meet higher food demands, and increased usage of water in industry, energy, and urbanization development. In consequence is the vulnerability toward the sustainable development and the country will be faced with enormous problems to be solved. These problems are varied from nutritional, health, educational, poverty, poverty related crimes, societal concerns and the ultimate impact on national security.

Another factor that has added to the scarcity of water in Egypt is excessive watering and the use of wasteful irrigation techniques (i.e. the flooding irrigation techniques). This system of irrigation has allowed the irrigation water that is withdrawn from the network that comes from the Aswan High Dam, which regulates more than 18,000 miles of canals and tributaries of the Nile (*MWRI-EGYPT, 2014)*, to be pushed to the country farmlands. This is an inefficient system that allows for the loss of as much as 3 billion cubic meters of water per year. Further, the evaporation of this water from these techniques adds to the problem of scarcity of freshwater in Egypt. An additional factor of the scarcity of water is the water pollution of the River Nile from industries along the river. This loss and pollution of water could add to the scarcity of water by reducing the available arable lands for producing crops. This decline in the fertile and productive lands, which are the biggest employers of youth and many workers in the country, will lead to increasing unemployment.

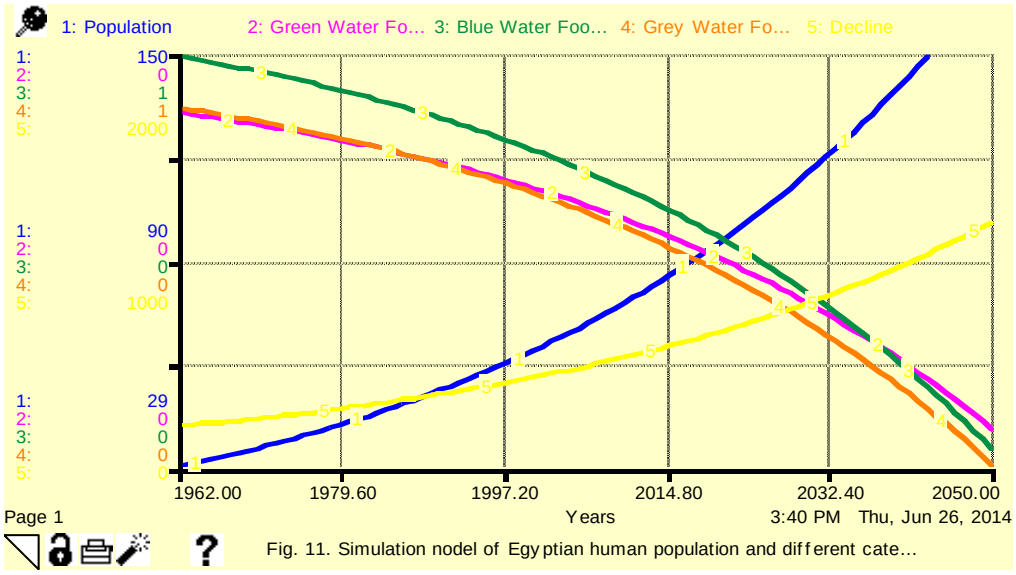


Figure 11: Simulation model for Egyptian population and water categories (i.e. green, grey, and blue water footprint at the 2% annual growth rate) and declining water resources. Blue represents the Egyptian population, green represents the blue water, purple represents green water, red represents grey water, and yellow represents the decline in useful water resources

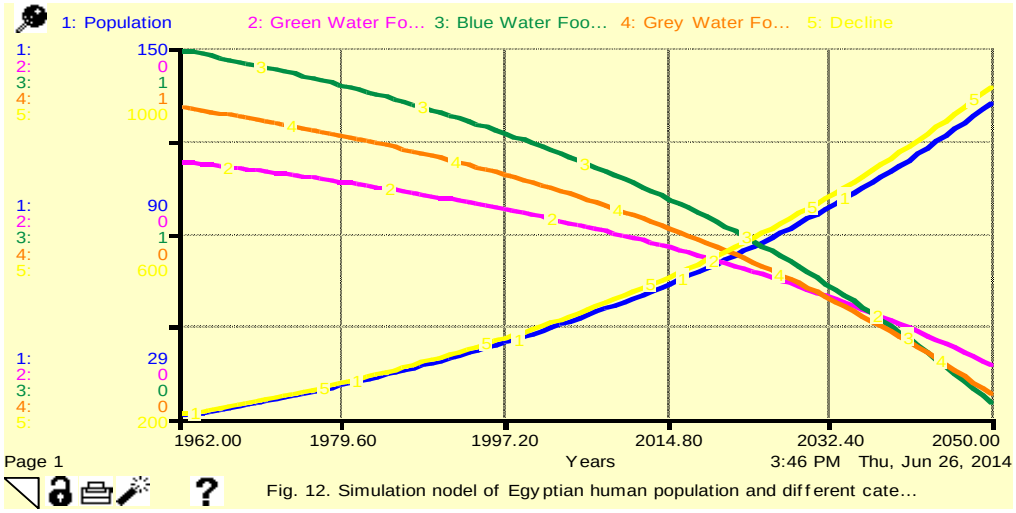


Figure 12: Simulation model for Egyptian population and water categories (i.e. green, grey and blue water footprint at the 1.7% annual growth rate) and declining water resources. Blue represents the Egyptian population, green represents the blue water, purple represents green water, red represents grey water, and yellow represents the decline in useful water resources

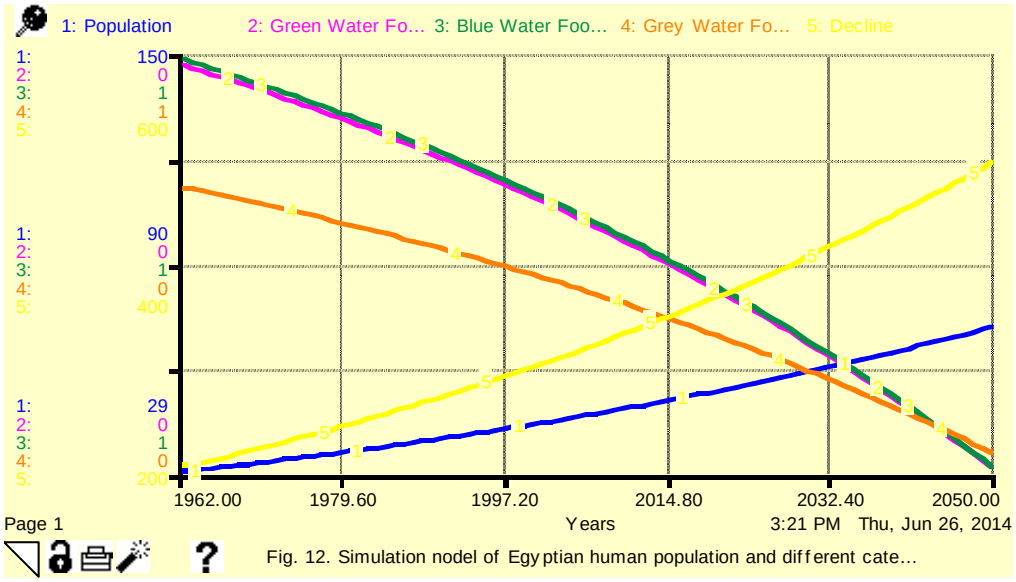


Figure 13: Simulation model for Egyptian human population and water categories (i.e. green, grey and blue water footprint at the 1% annual growth rate) and declining water resources. Blue represents the Egyptian population, green represents the blue water, purple represents green water, red represents grey water, and yellow represents the decline in useful of water resources

Furthermore, there is a complicated situation for Egypt to use more water of the Nile basin because the more rapid increase of human growth rate in Egypt and in African countries. The river Nile is supporting ten countries along the River Nile; these countries have demanded more shares of the River Nile Water (i.e. from the countries along the upper stream of the river [European Foresight Platform (EFP) Brief No. 252, 2011. In this respect; the upper-stream countries are building dams and other water projects on the River Nile to meet the demands of their growing populations for water for irrigation, crops, and industrial development. This will prevent the rainfall on the upper stream lands on the river from flowing down and will slow water flow to the mouth of the River Nile. This will have disastrous environmental consequences in the downstream countries such as Egypt and Sudan. This condition creates more water scarcity for Egypt, endangers the country's stability, creates chaos politically, and endangers the welfare of the surrounding regions.

Discussion and Conclusions

Water resources in Egypt are vital. Without water, no organism can survive. Egypt depends on the River Nile Basin for 97% of its water resources for agriculture and production of agricultural products. The industrial sector, drinking water, municipalities, navigations, and power plants are also dependent on this water. The scarcity and the reduction of rainfall, surface water, drainage, the reuse, and sewage use of water are the leading concern for the sustainable development and continuation of building ecological capacities for supporting the human population of Egypt. Due to the increasing human population and increasing demands for water resources, the water policies of the 1970s and early 1980s gave a significant advantage for the new land development processes. However, recent changes in price and other policies, particularly the reduction/elimination of government fertilizer and energy subsidies, place farmers in the new land at a disadvantage (ICID 2004).

Various demands for freshwater are putting excessive pressure on the available water supply. The agricultural sector (including fisheries) is the highest freshwater consumer, utilizing about 78% of the available supplies (excluding recycling), while the domestic and industrial sectors consume 7% and 7.6% of the total natural supplies (National Planning Institute (NPI), 2008). The navigation and energy (i.e.

hydropower) sub-sectors are "in stream" users, meaning that they utilize the Nile/irrigation distribution system, but they are not net consumers of the water resources. Drainage water spilled to the Mediterranean Sea and the desert fringes of the Nile system contribute to the water needed to maintain the ecosystem/ habitats of the northern Delta/Lakes. Evaporation loss from the 31,000 Km-long water conveyance network is estimated at 2.4 billion cubic meter / yr., (Wagdy, 2009, IDSC, 2007).

The challenge of water resource development in Egypt is that the Nile as the single source water, uncertainties in climate, developments upstream, and population growth has characterized efforts to anticipate potential future water constraints. Municipal and industrial water use is being readily met. Agricultural water use yields high levels of production with about 200% cropping intensity. However, the costs for water services for the next 15 years will be more than triple the current expenditures. Future public sector allocation for such high costs presents a heavy and unsustainable burden for the government budget. Moreover, water quality in a closed system is deteriorating because of pollutants being retained, as part of the recycling and reuse of drainage water, along with poor treatment and regulation of urban and rural sanitation (Ministry of Water Resources and Irrigation, Arab Republic of Egypt, 2005). Another challenge, globe warming induced alterations in the Nile's hydrologic cycle will tend to reduce Nile runoff, thus limiting irrigation water availability. Shortages of water will probably constrain food production and other economic activities. Additionally, agriculture intensifies water quality and salinization problems are likely to worsen. Increasing competition over scarce water resources will tend to aggravate conflicts with other Nile states. The fisheries industry is likely to be declined and affected. As the consequence, the reduction of agriculture production, the nutritional condition of individuals, as measured by calories and protein intake per capita is projected to deteriorate implying increased vulnerability to diseases and health problems. In addition, the decline in equivalent income reinforces the possibility that poor households may have to do with lower incomes, which outcome makes them physically more vulnerable for food is not all that is necessary for attaining a minimum standard of living. There are other non-food requirements, such as housing, transportation, clothing, etc, each of which will become less affordable in the event that more of the income is allocated to food which on average already accounts for about 50% of total household expenditure in Egypt (Onyeji and Fischer, 1994).

The important issue now for Egypt is to develop a planning scheme to 1) ensure the long-range planning of using the water of the Nile sufficiently through conservation and reuse of the water, 2) establish a good system for preserving the water commodities by recycling, 3) conduct negotiations with African countries to protect the share of Egypt's water from the River Nile, and 4) collaborate with the African countries to establish a friendly dialogue and sign a memorandum of understanding between the African countries on the River Nile to ensure the sustainable development of these countries by exchanging experts from these countries to ensure the utmost utilization of the water resources of the Nile basin, 5) Egypt should search for alternative sources of water through the desalinization of sea water from either the Mediterranean Sea or Red Sea (this will require long-term planning because this option is costly and expensive), and 6) conduct long-term sustainability planning to control the human population growth in Egypt. In our own views, the development and sustainability progress should be in a trend to exceed the population growth rate in order to make sustainability work, to reduction of wastes and further optimum use of the existence of the natural fully.

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