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Research paper

Impact of sea-level rise on groundwater salinity at the development area western delta, Egypt

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ABSTRACT

Climate change effects are expected to raise the average sea level. It is widely assumed that this raise will increase saltwater intrusion processes in coastal aquifers. There are four scenarios for sea level rise (RCP2.6, RCP4.5, RCP6.0, and RCP8.5), which were assumed in the year 2014 by the International Panel on Climate Change (IPCC, 2014). The two extreme scenarios (RCP2.6 and RCP8.5) are considered in this study to examine the impact of the expected changes in the Mediterranean Sea level on groundwater salinity at a relatively new development area in Egypt at the west of the Nile Delta. Rising in sea level would destroy parts of the protective offshore sand belt, which has already been weakened by reduced sediment flows resulting from the construction of dams in the Nile. Without this sand belt, water quality in coastal freshwater lagoons will be altered, and recreational tourism and beach facilities will be inundated. The tools of Geographic information systems and Numerical simulations, using the software "ArcMap" and "FeFlow" respectively are used. The simulations are conducted in 3D using digital elevation model. For three scenarios of sea level rise (RCP2.6, RCP8.5 and the scenario of no rise in sea level), two different ways for groundwater extraction rates are considered: the first is the actual extraction rate, and the second is the extraction rate at the initial condition in the year 1990. The simulations show that the effect of global sea level rise in the period from the year 1990 up to 2100 appears clearly through the coastal topography with relatively low level elevation adjacent to the shoreline. A shift of the interface is expected up to the year 2100 by a maximum of 43 km covering an area of 1980 km^2 according to scenario RCP2.6, and by a maximum of 57 km covering an area of 2870 km^2 according to scenario RCP8.5. Overexploitation of groundwater leads to an increase in salinity concentration up to 5000 mg/l and covers about 10% of the study area.

1. Introduction

The latest report of the Intergovernmental Panel on Climate Change (IPCC, 2014), reflecting the views of scientists from over 130 countries, confirmed that global sea level has already been rising at an average rate of 1.7 mm per year during the 20th century. With continued growth in global greenhouse gas emissions and associated warming, sea level could rise by another one meter this century. Most of this anticipated increase is attributable to glacier melt and thermal expansion of oceans. The additional possibility of warmer temperatures unexpectedly breaking up the Greenland and West Antarctic ice sheets, still widely debated among climate scientists, could lead to a devastating increase. The report of the International Panel on Climate Change (IPCC) includes expected information on climate change and sea level rise based on Green House Gas (GHG) emissions that are influenced by: population size, economic activity, life style, energy use, land use patterns, technology and climate policy. According to these influences, the IPCC made four representative concentration pathways (RCPs) to describe 21st century pathways of GHG emissions and land use (IPCC, 2014). The RCPs include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0) and one scenario with very high GHG emissions (RCP8.5). The chosen socio-economic climate change scenarios give a likely range of sea level rise (for the period 2081–2100) in between 0.25 and 0.55 m for scenario RCP2.6 and 0.45–0.82 m for scenario RCP8.5. This research presents the impact of the expected 21st century sea-level rise and groundwater extraction on groundwater salinity at the development area western Delta, Egypt. The western Nile Delta region covers the area between Cairo and Alexandria, west of the Nile "Rosetta branch", and due to

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its location, accessibility, and investment facilities provided by the government, this area is characterized by a rapid development based on surface and groundwater in the fields of agriculture, industry, and recreation investments. Many researchers have studied the phenomenon of sea level rise. By the end of the 19th century Ghyben (1888) and Herzberg (1901) indicated that sea water intrusion into coastal aquifers is a long-studied problem. A number of investigations have developed chronologies of sea level variation extending over the past 50,000 years (Shepard 1963; Shepard and Curray, 1967; Milliman and Emery 1968; Kraft et al., 1973). The results generally agree that about 15,000–20,000 years ago, the sea was approximately 100 m lower that at present. Lately by the end of the 20th century and the widespread of the numerical models many researchers have investigated this phenomenon and its influences, for instance: Bear et al. (1999) reviewed several numerical models with sea water intrusion simulation capabilities, including SHARP, SUTRA, HST3D, MOCDENS3D, and an early version of FEFLOW, Loáiciga (2003a) reported a methodology to assess the impacts of climate change and groundwater extraction on aquifer recharge and springflow, Nicholls and Cazenave (2010) estimated a GMSL rise of approximately 3.3 mm/year in the period 1992–2010, Anderson et al. (2010) and Nicholls and Cazenave (2010) indicated that the impacts of sea level rise will become more apparent, especially in certain low-elevation coastal zones, Chang et al. (2011) concluded that: if the ambient recharge remains constant, the sea-level rise will have no long-term impact, Loáiciga et al. (2012) pointed out that variations in groundwater extraction (anthropogenic fluxes) was the predominant driver of sea water intrusion in a model that simulated sea-level rise scenarios for the City of Monterrey – California, Ferguson and Gleeson (2012) described the relationship between hydraulic gradients, population density and known saltwater intrusion cases at specific locations in the contiguous United States, Gleeson et al. (2012) pointed out that groundwater sustainability is not possible without management, monitoring and characterizing of groundwater resources, water managers, local communities, and hydrogeologists should work together to set long-term goals, to device polices and measures by backcasting,

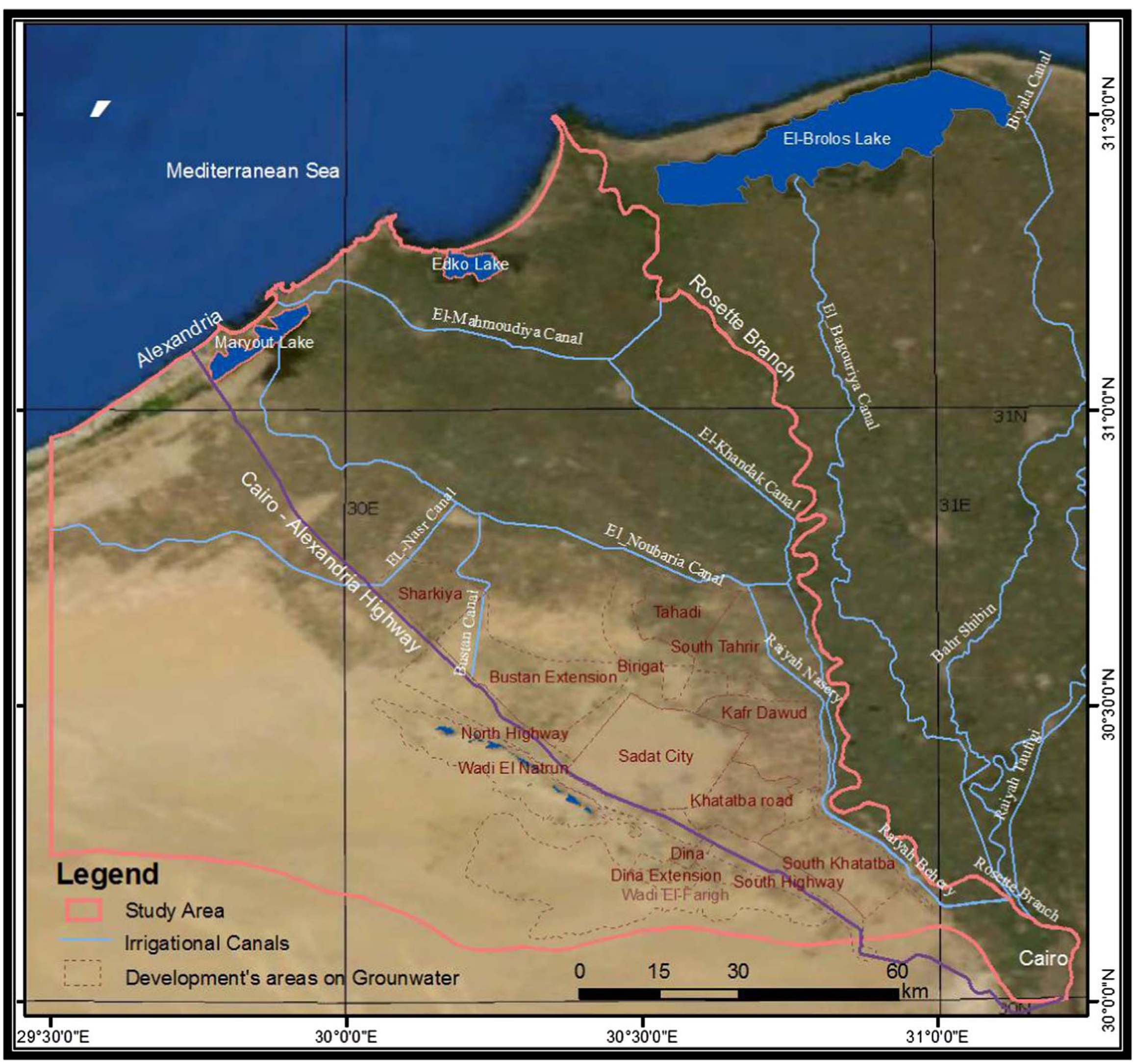

Fig. 1. Outlines of the study area with main features and names.