MINISTERUL EDUCAȚIEI NAȚIONALE
ROMÂNIA
UNIVERSITATEA DE MEDICINĂ, FARMACIE, ȘTIINȚE ȘI TEHNOLOGIE „GEORGE EMIL PALADE" DIN TÂRGU MUREȘ
sciendo

Acta Marisiensis. SeriaTechnologica
Vol. 17 (XXXIV) no. 2, 2020
ISSN 2668-4217, ISSN-L 2668-4217

10.2478/amset-2020-0018

MODELING IN WATER RESOURCES MANAGEMENT IN EAST NILE DELTA: Review

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ABSTRACT

It is acknowledged that providing a safe water supply for all countries is one of the major challenges of the twenty-first century. Egypt is one of the greatest countries affected in Africa and Middle East. The Nile is facing a major water shortage due to the limited water resources and the the demand is growing as a result high population growth and development in industrial and agricultural sectors. This paper has been motivated by the fact that there is no up-to-date literature review of the optimal operation of Water Resources. The analysis of the reviewed literature is structured along five broad branches: (1) Mathematical Optimization Modelling Studies, (2) Numerical Simulation Modelling Studies, (3) Geographical Information Systems "GIS" based Studies, (4) Ecological Studies, (5) Water Reuse Studies. This review is limited to surface water but groundwater has been inexplicitly included. The paper concludes the best way to identify knowledge to cover the gap between water supply and demands and to guide future researches on water resources planning and management.

Key words: Optimization, Simulation, GIS, Ecological Studies, Water Reuse

1. Introduction

The world is facing intense and increasing challenges in preserving water quality,meeting also the rapidly increasing water demands. For Egypt, the Nile provides almost all fresh water used by more than 80% of the Egyptians living along its banks. Since Egypt faced the growth of the population and the increase of the agricultural and industrial sector, Subsequently the country suffered from water shortage. Many studies have been done all over the world on Optimal Operation of Water Resources on many watersheds and on the river Nile basin since 1981 until now. These studies are presented under different categories (Climate change studies, GIS modelling studies, Numerical and Simulation modelling studies, Optimization modelling studies and Ecological studies).

Multi-criteria Decision Analysis (MCDA) was used to compare all desalination alternatives for Egypt, considering the use of desalinated water, source of feed water, desalination technology, locations of the plants, and their capacities [1] and a multi-objective goal programming approach was used to simulate water distribution from multiple sources to multiple users for the city of Riyadh, Saudi Arabia for over a thirty five year period [2]. An integrated two-step model was developed. This model is based on the fuzzy-analytic hierarchy process (AHP) and technique of order preference by similarity to ideal solution (TOPSIS) methods for the selection of the optimum desalination technology [3]. Resources for water supply were allocated in order to choose the city in which a water supply system project will be implemented. They applied the elimination and choice expressing reality

(ELECTRE) method, a multi-criteria decision-aid support tool. They compared their model results to decisions based on intuitive judgments and concluded that the use of their method improved the quality of the decision making process [4]. The optimization model was developed for supplying sources (conventional and non-conventional ones) within considering water quality [5].

GIS was used based on groundwater in West of Nile Delta and supplies the exploitation of analytical tools and the conception capabilities for the information implicated in models of groundwater for the case study [6] and images of satellite of Landsat Topical Mapper (TM) 1992. Landsat Reinforced Topical Mapper (ETM) 2001 and Egypt Sat-1 2009 have been used to study the urban sprawl impact Assessment on the fertilized agricultural land of Egypt [7]. Evaluated water quality of the Nile River branch of Damietta at Dakahlia and Damietta governorates [8] uses HadCM3 model predictions to investigate the effects of global warming on water resources in Saudi Arabia in 2050 and concluded that increasing temperature by (1.8–4.1) C° will lead to increase agricultural water demands by (5–15)% [9]. The main aim of this paper is to present the state of the art review concerning optimization modelling studies for optimal operation of water resources management and to identify knowledge gaps where more research is needed. This paper has been motivated by the fact that there is no such up-to-date study for this critical and highly importance topic, especially in water scarce countries like Egypt. The paper covers studies on (1) Mathematical Optimization Modelling Studies, (2) Numerical simulation Modelling Studies, (3) GIS modelling Studies, (4) Ecological Studies, and (5) Water Reuse Studies,. In the context of each approach, different aspects of the system were assessed, such as physical, hydro-economic and environmental aspects. This review is limited to surface water including not explicitly method groundwater, Treated sewage water and Recycling of drainage water.

2. WATER RESOURCES MANAGEMENT AND MODELLING PROCESSES

In the past, Egyptian water policies were made up under the prime of the continuous availability of surface freshwater. At that time, the clear policy choice was to evolve water resources to the maximum possible. Technological and financial-technological constraints were seen as the only limitation to evolve. Economic feasibility was the main criterion for the approval of water resource projects. This meant that the analysis process used for policy formulation had well defined aims. However, in order to meet the increasing demand for socio-economic development, the supply of surface water from the Nile had to be augmented with marginal-quality water and high-cost groundwater [10], and an hydrological model had been made and analyzed for the long-term Nile River flows [11]. Three models for flow hydrograph forecasts were also made, and they were simulated at Hydro stations of Blue Nile [12] What's more, a model for groundwater management for irrigation was constructed, and its salinity was calculated. [13], Fig. 1 shows the operation flow chart for model processes.

3. TYPES OF OPTIMIZATION MODELS STUDIES

Optimization modeling (OM) has a great importance in different engineering fields. In water resources management, the OM is mainly used to (1) Find the best way to meet different objectives of reservoir system management [14], (2) Develop the hydrology tools of inferred analysis to be used for making at the scale of River Basin for the decision of water allocation [15], (3) Provide planning information, that is difficult to get by mixing surface water and groundwater, through the water system [16], (4) Study the groundwater management, its quantity and its salinity [13], (5) Study the efficiency of water use in irrigation management systems and water balance by using numerical models [17]. There are many studies for Optimization Modelling . These studies are presented under the following broad categories:

1. Mathematical Optimization Modelling studies,
2. Numerical simulation Modelling studies,
3. GIS-based modeling studies,
4. Ecological Studies, and
5. Water Reuse Studies.

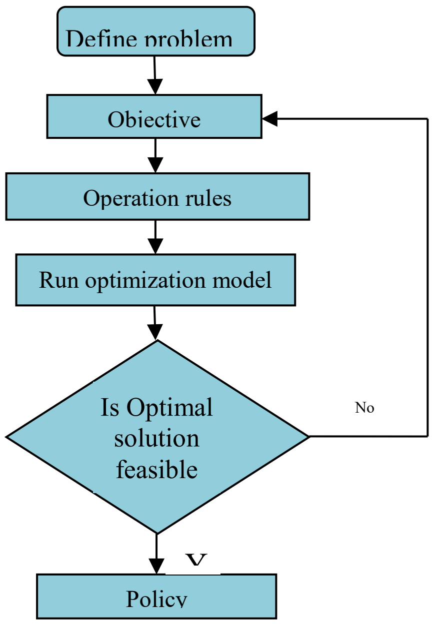

Fig. 1; Operation flow chart

3.1 MATHEMATICAL OPTIMIZATION MODELLING STUDIES

The model has been applied in North Taiwan, and consists of arcs and nodes used to form the network, and storage supply for domestic and agricultural uses. The main objective is to minimize water demands by collecting the products of the variables through their coefficients of corresponding cost. The model constraints include decreased water supply, continuity equations, rule curves of reservoir operation, because of water losses, and water shortage from reservoirs. Comparing the results between simulation and optimization models has showed that the water shortage calculated by optimization model is smaller than the one calculated by the simulation model [18].

CALVIN has been used. It is an economic-engineering optimization for the water system in California used to provideplanning information that is difficult to get by mixing surface water and groundwater. The results showed that water conjunctive is used to improve economic value and performances to expand conveyance facilities and models which motivate the surface water-integrated and systematic treatment, the facility, the water demand data the groundwater and identification of data problems, types of long-term value of analytical water resources [19].

The integrated hydrologic-economic model has been applied on the conjunctive of groundwater and surface water (River Basin of the Adra, Spain). The river basin modeling allows to simulate the groundwater. Constraints are warranty the feasibility and suggested operations' sustainability. The results showed the monthly flow and the series of storage time for all elements of modeling system, water economic value at each time step and location, and upper or lower sides in reservoirs in prices, pipelines, canals and stream reaches [20].

(CALVIN) optimization model has been made to reuse waste water and water desalination with future Forecasts for population and water demands in Ensenada, Baja California, Mexico and to explore and mix alternatives of integrated water management, within the constraints of physical capacity and available water in regions, minimizing economic costs of water shortage and the costs of operating within a region. The results showed that reuse and reclamation of wastewater for Ensenada is the most economical alternative selection to meet the future water demands and to make the imports of water less attractive. Desalination of Seawater and other options are not economical fertile alone [21].

The optimization model was developed for supplying sources (conventional and non-conventional) within considering water quality, water distribution capacity and present connections between water supply and water demands, applied to the model on a basin of a Spanish Mediterranean river which suffers from water shortages. The results showed that the model provides an innovative tool to investigate the water allocation for improving the water resources management in water deficit areas [5].

3.2 NUMERICAL SIMULATION MODELLING STUDIES

Step directions of the flow time series of the Nile River had been analyzed, using two statistical softwares, based on the hydrologic year (June-May) The long-term Nile River flows has also been analyzed. The results showed that there was a high interconnection between the stations on one side of the Blue Nile and the Nile and on other side of the Atbara River, and a weak interconnection between the stations on the White Nile and on the Nile that indicated that there was a strong impact on the flows of the Nile by the flows of Atbara River and the Blue Nile [11].

The Blue Nile Flood diffusion had been presented in Sudan by using Three models. Water level and flow hydrograph forecasts were updated and simulated at the Hydro stations of Blue Nile [12].

The appropriate schedules of water in greenhouse and open fields were detected using drip irrigation for different vegetables and the evapotranspiration of crops and water used in irrigation was calculated by using the Penman-Monteith method [22].

OPDM (Operational and Planning Distribution Model) Model has been used in Bahr Mashtoul, Egypt, a study area to analize the groundwater management. Groundwater quantity changes that have been used in irrigation from -50% to 50% and changes in salinity of groundwater from -50% to 50% have been studied, showing the effect on the incomes of each crops [13].

3.3 GIS BASED MODELING STUDIES

The part of Northern Nile River Delta area had been studied with a coastal zone on the Mediterranean which is about 120,000 hectares, by using Multi-Criteria Evaluation (MCE) techniques and GIS to represent the area's different economic, water-environmental and social factors. Different scenarios were proposed for random cropping pattern distribution. Through the combination of GIS and MCE, three scenarios were evaluated at three different levels: whole area, farm and canal catchment area. This combination resulted in a very strong tool to evaluate the different plans and really facilitated decision making for different types of integrated water management problems [23].

GIS and Remote sensing techniques had been applied to integrate the divest source of contamination, the hydrogeological data and to map the critical areas for constructing the protected Ismailia canal buffer zone and for constraining the evolution activities in the surrounding areas of surface water supplies. Selecting the areas had been done based on specific hydrogeological criteria, geology and soil properties. The natural ecosystems of morasses around Ismailia Canal are recommended to be conserved and the methods of continued burial to be prevented [24].

A new support method of participatory decision had been used in transboundary presented basins. The frame of this method relies on the transboundary creation of GIS database to store hydrology data and to allow access from stakeholders to data. Results are visible and show that the Jordan River countries can benefit from the frame work, and in south Lebanon's case, six climate stations could be replaced or reactivated. The mechanism of an Information System of Lebanese Hydrologic is presented and shows that the data of observation model will facilitate knowledge and integration of policies [25].

GIS and Remote sensing had been widely used in groundwater mapping in the Nile Delta, Sinai Peninsula, Nile Valley and Western Desert Oases which considered the main tools for developing groundwater resources [26].

3.4 ECOLOGICAL STUDIES

The Nile problem has been examined from an Egyptian viewpoint. The Nile is the main source of water in Egypt. This explicates why water is a key of security issue, from Egypt's viewpoint, and why coordination with the upstream of Nile countries is the only ahead way for Egypt. Egypt water policy is the center of demand management, international projects and environmental protection for increasing the water supply [27]. The quality of river water has been analyzed at the outlet of drain of El-Rahawy in Rosetta branch, Nile delta. Water samples were collected annually from Rosetta branch and El-Rahawy and analyzed conform to the sequent physicochemical parameters: concentration of hydrogen ion (pH), electric conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), total alkalinity (CO_3 HCO_3), ammonia (NH_3), chemical oxygen demand (COD) and biochemical oxygen demand (BOD). They were then compared to the results and standards of the water quality of Egypt. Increasing TDS and NH3 with decreasing DO, COD and BOD values in drain of El-Rahawy led to a serious deterioration of the water quality in the downstream of Rosetta branch [28]. Water quality index (WQI) was used to evaluate the quality of water in Ismailia canal according to utilizations of Irrigation, Industry, drinking and aquatic life. The Index transforms the data of quality water into usable information. The WQI values of Ismailia Canal are good for drinking, irrigation and aquatic life. (MI, Al^{+3}, Fe^{+2}, Pb^{+2}, Cd^{+2}, Mn^{+2}, Zn^{+2}, Cu^{+2}, PI and Ni^{+2}) were calculated to evaluate the pollution of the canal water. The study showed that there are dangerous wastes in the canal so law 48/1982 must be implemented to prevent the deterioration of the water and to improve the water quality [29].

The fifty nine samples of water had been collected from different network of canals while the water suitability was studied for different uses. GIS was used to detect the variation quality of water in canals and to produce maps for the quality of the water. The canals were classified into classes ranging between low and high water quality. The results might assist to a detailed overview of the contaminated reaches in the studied canals to help in the process of management for important water resources [30].

3.5 REUSE WATER STUDIES

Because of limited water resources in Egypt, unconventional resources can meet the difference between water resources and demands so it is very important to reuse treated wastewater and drainage water.

3.5.1 Reuse of Drainage Water

The limited agricultural drainage water reuse was used by the concentration of the salinity of drainage water which Moves from upstream to downstream, and although the standard of salinity increases, the salinity of most of the valley and of the southern Delta remains under the critical level (1,000 ppm), which makes them potential to reuse. However, in the north of the Delta, a lot of quantities of salt spew through groundwater to the agricultural drainage water because of the seawater intrusion. The seawater which discharged into the drains is predestined to be about 2.0 BCM/year. This water is pumped again to the sea and the north of the lakes to maintain the balance of the system salinity. So, a more efficient irrigation leads to the same amount of dissolved salinity in a little amount of drainage water. This means smaller quantities of drainage water reuse will be concluded with a more efficient distribution system [31].

The impact of tile irrigation canals was evaluated to improve the irrigation water quality and three canals which pass across the residential area at Abu Kebier, Sharkia, Egypt were selected. Samples of Water were collected from the tile canals at different locations, then the samples were analyzed in laboratory to obtain the parameters of water quality. The study showed that the covering of irrigation canal did not improve the quality of water at the section of covering compared to the point of reference at the upstream and also showed that the parameters of water quality were affected negatively by the present covering [32]. The samples of soils from 10 sites were collected and wheat along the drain of Belbeis with 5 Kilometers distance sites and they were analyzed to find the percentage of Pb and Co. The study showed that the percentage of Pb in the water was through the permissible levels and increased along the drain and the percentage of cobalt increased more the permissible levels. Using this water in crops irrigation is very dangerous [33].

3.5.2 Reuse of Treated Wastewater

On the other hand the treated wastewater was used without mixing it with freshwater in irrigation. The growing demands for domestic water because of population growth and the growing use of industrial water because of the future protraction in the Egyptian industrial sector will make the total amount of wastewater available to reuse grow. There are few treatment plants for the collected wastewater in big cities in Egypt.

The farmers used treated wastewater to irrigate in developing countries due to the limited available freshwater, the limited available nutrients, the lower cost compared to pumping groundwater and the nearness to treatment plants. The cultivation of the forest to produce wood is the main consumption of treated wastewater (TWW) in Egypt. The Ministry of Agriculture and Land Reclamation, the Ministry of State for Environmental Affairs, and the Ministry of Urban Communities Housing and Utilities have declared that 2.4 109 m3 of TWW have been used for forests and greenbelts. Recently, desert areas near to wastewater treatment plants have been reclaimed. The areas are about 155,500 feddan and used TWW for irrigating bio-oil crops and forests (Ministry of State for Environmental Affairs, 2015) [34]. The successful story of TWW use was recounted in the Serapium Forest (located in the Ismailia governorate), in Egypt. In arid environment, various types of trees which provided in Serapium a high wood yield, were well-adapted. Farahat & Linderholm (2015) showed that a safe strategy would be the decrease of the various species' consumptive efficiency and of the toxit trace proficiency of the metal concentration. Soliman & He X (2015) showed that since the late 1990s, TWW is used for cultivating Jatropha (bio-oil crop) in Egypt. Recently, using TWW for cultivating 2000 feddan in Upper Egypt governorates had a good economic potential [35].

4. CONCLUSIONS

Most of the reviewed researches depend on a physical model which is a good hydrological modeling approach for studying the river basin management in small scale but does not take into consideration many parameters that may effect on the model output. Mathematical modeling therefore can be considered the best hydrological modeling approach, and can be divided mainly into two main groups of models:

1. Simulation models, used to simulate river basin as a unit of water resources, and
2. Optimization models which take the operation rules imbedded in the model as constraints under the objective function.

Simulation models based on GIS are a good representation of river basins, used to study the different operation scenarios of the river basin, but they have the dis-advantage that they are an expensive computation for large systems. Network approach is the best method for studying the complex systems by using integration between the different parameters or operation constraints to control the river basin management.

5. RECOMMENDATION

Based on the previous studies, it is recommended to develop the following research points:

(i) A multi objective optimization model containing the interdependency between the river sharing countries that have different operational rules, which increases the efficiency and effectiveness of the operation process, (ii) A locally detailed optimization model should be developed, to provide operational guidelines that take into consideration the different management variables,the salt balance for surface, and groundwater, to obtain the optimal operation,

3. Consider evaporation, seepage losses and precipitation forms in the future studies,
4. Study climate change impact on water resources and demands, and
5. Study economic factors with GIS affecting water resources.

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