Changes in a Coastal Lake Dynamic System and Potential Restoration

Hala Abayazid

Abstract Northern coastal zone of Egypt hosts lakes with distinguished characteristics. Earlier, certain coastal lakes were acknowledged as nature reserve, with their rich aquatic environment as well as playing a hosting role to migratory birds. However, maintained conditions with ever-expanding development activities are a challenge. This chapter addresses aspects in the changing structure of coastal lakes; governing factors responsible for the declining dynamic system. Hence, challenges with sustainability and capacity to recover are discussed. As remote sensing techniques proved cost-effective tool, with reasonable accuracy, for monitoring temporal and spatial changes, an application is presented to a case study of the deltaic coastal lake, Lake Burullus. Among the wide information that can be derived from satellite imageries, water quality index is selected as a key indicator to gain insight into evolving environmental state of the coastal lake. Finally, the chapter discusses proposed strategies to regain efficient functionality and sustainable beneficial uses of coastal lakes, while considering applicability.

Keywords Coastal lake, Dynamic system, Egypt, Hydrodynamics, Remote sensing, Restoration, Water quality index

Contents

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1 Introduction

Egypt is rich with natural resources that play a main role in the development processes, among which are the coastal lakes. Located north of Egypt, five lakes, namely, Bardawil, Manzala, Burullus, Idku, and Mariut, acquire special geographic and environmental importance. These lakes occupy a transitional position between the Mediterranean Sea and the Nile river network. For decades, coastal lakes have been the sponge alleviating pollution impact of wastewater discharges before reaching the sea. Besides, coastal lakes are responsible for greater part of fishery production and, in turn, cover an important socioeconomic sector in the country. Moreover, while acknowledged as a nature reserve with rich aquatic life and role as a stopping point for migratory birds, coastal lakes are also expected to act as buffer and important defense line to potential climate change-related sea level rise. Yet, all beneficial uses are compromised with severe deterioration in lake conditions that start to be alarming.

As development wheel advance, along with growing population and increasing needs, anthropogenic activities caused a drastic change in once considered a healthy ecosystem. Coastal zone, especially within the Nile delta, has witnessed increased agricultural, industrial, and fish farming practices as well as urbanization expansion that even invaded into lakes' open water area. Systematic discharge of agricultural drainage loaded with fertilizer, pesticide and herbicide residues, fish farms and industrial wastewaters, as well as partially treated domestic wastewater is a daily practice. Additionally, expanding urbanization in coastal lakes' served area has a slower rate of infrastructural development, which results in discharged wastewater with compromised treatment.

Excessive intrusion into lakes caused a drastic alteration in environmental condition and hydrodynamic mechanism. Destructive effects include deterioration of water quality state, high intensity of unwarranted vegetation, sedimentations and disturbance to water circulation, compromised functional outlets, and, consequently, disturbed water exchange with the Mediterranean Sea and altered salinity level within lakes. Challenges with changing environmental, physical, biological, and chemical conditions in coastal lakes have alerted concerned parties and triggered several research studies [1–8]. Also, El-Adawy et al. [9], Saad El-Din et al. [10], Rostom et al. [11]. Studies addressed concerns with the deteriorating conditions of coastal lakes in Egypt and gave special interest to those within the Nile delta region, for the environmental as well as socioeconomic importance in the development process.

As remote sensing techniques proved promising potential in monitoring temporal and spatial changes, with reasonable accuracy, an application is presented to a case study of deltaic coastal Lake Burullus. Among the wide information that can be derived from satellite imageries, water quality index is selected as a key indicator to gain insight into evolving environmental state of a coastal lake.

This chapter was designed to provide background information on Egyptian coastal lakes and main issues of concern on changing system within that eventually reflected on water quality status. Aspects of the altered structure and inner mechanism of lakes are highlighted, along with the governing factors responsible for declining dynamic system. On this basis, challenges with sustainability as well as capacity to recover are reviewed. However, proposing remedial strategies to regain efficient functionality of coastal lakes should address the dilemma between effective recovery measure and practicality in an actual application with inevitable continual developments.

2 Developments Versus Sustainability

During the last decades, the concept of sustainability with development activities was mainly following the definition "sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs." However, with continual anthropogenic pressure and undeniable threats to the ecosystem, the United Nations Development Programme (UNDP) issued a renewed commitment to sustainable development goals, effective in January 2016, which acknowledge concerns in water sector such as life below water and clean water.

2.1 Aspects of Changing Features of Coastal Lakes

The discussion will be ruling out Bardawil Lake. Being fed only by seawater and characterized with minimum developments and anthropogenic interference in served watershed [1, 12], this lake is considered unique among the Egyptian coastal lakes. Oppositely, lakes within the Nile delta region experienced drastic changes. Significant shrink in the surface water area, extended earth-filled parts, and an increase in the vegetative cover ratio are the visibly figured changes in deltaic coastal lakes. To have an illustrated validation, changes in Normalized Difference Indexing for Vegetation and Water (NDVI and NDWI) from the year 1984 to the year 2014 were quantified using Landsat imageries green, red, and near-infrared bands. Figures 1 and 2 demonstrate results of systematic lake invasion and loss of

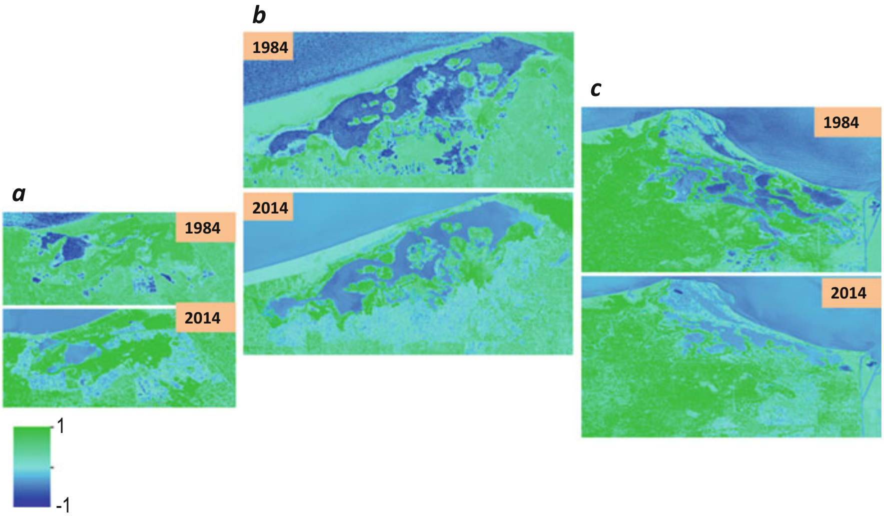

Fig. 1 Change in Normalized Difference Vegetation Index (NDVI) from 1984 to 2014 in three deltaic coastal lakes. (**a**) Idku Lake. (**b**) Burullus Lake. (**c**) Manzala Lake

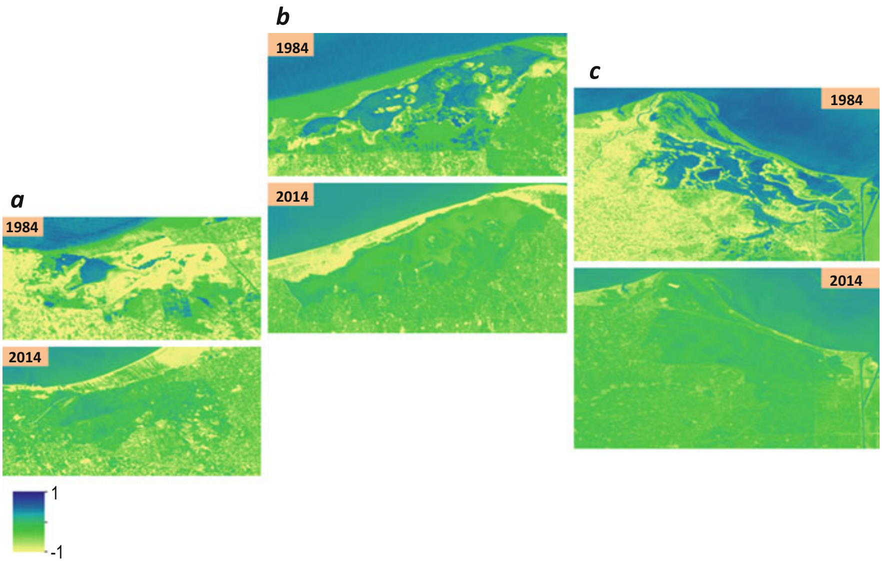

Fig. 2 Change in Normalized Difference Water Index (NDWI) from 1984 to 2014 in three deltaic coastal lakes. (**a**) Idku Lake. (**b**) Burullus Lake. (**c**) Manzala Lake

natural structure for selective deltaic lakes, namely, Idku, Burullus, and Manzala, represented in the form of NDVI and NDWI, respectively.

It is hard to pinpoint one specific main cause, land reclamation, modern agricultural practices, expanding urbanization, insufficient infrastructure, industrialization, etc. Yet collective contribution results in the observed deteriorating condition, with different degree. In some sort of sequential cause-effect interpretation, following three components would help summarize the changing pattern.

2.1.1 Sea Water Exchange and Salinity Level

Originally, deltaic coastal lakes are directly connected to the Mediterranean Sea through inlets. In a balanced environment, the direction of currents alternates mainly due to the tidal force, experiencing direct effects of either ebb or flow. Yet wastewater discharges into lakes conquer the exchange rate with seawater through inlets. That, in turn, decreases salinity concentration within the lakes, causing change in biophysical structure, and consequently disappearance of once-common aquatic species and fish production, as reported from local settlers. Further, low water salinity level provokes vegetation intensity, which dictates water health state, not to mention trapped flow and sediment transport, weakened circulation, etc.

2.1.2 Nutrient Loadings into Lakes

Lakes assimilate excessive nutrient loads from various sources, municipal sewage discharges, extended fish farms, industrial wastewaters, and agricultural drainage influx with a drastic increase in nitrogen fertilizers consumption since 1980, according to the Egyptian third national communication. Besides the obvious water quality problem associated, nutrient enrichment encourages both floating and rooted aquatic plants. Increased nutrient-derived vegetation causes trap for natural water movement and smooth circulation. Slowing water velocity causes sedimentation and expanded islands within the lakes.

2.1.3 Internal Circulation and Localities of Sand Accumulation

Obstruction of flow dynamics and created segmentation resulted in weak circulation, a locality in the quality state with possible stagnation, expanded island existence, and loss in the water area. Therefore, formed zones within the coastal lakes are expected to have a direct effect on mixing process, water quality, and sediment transportation mechanism.

A vicious circle, change in salinity, and nutrient content cause extending vegetative cover that causes water slowing and sediment accumulation, causing an alteration in flow dynamics and inefficient circulation, and loss of naturally occurring self-purification, hence further salinity and nutrient disturbance.

2.2 Understanding Impact on Functional Dynamic System

This section intends to reflect the previously mentioned changing features into hydrodynamic behavior within a coastal lake system. As an intermediate region between the coastal regime and freshwater network, northern lake region has a complex hydrodynamic system. Principally, changes in a lake as a control unit are governed by conservation laws of fluid mechanics, conservation of mass (continuity), conservation of momentum, and conservation of energy [13–15].

In hydrological system of a lake, mass balance for water budget is governed by inputs, including inflow from point sources, such as wastewater treatment plants (WWTPs) and industrial facilities, tributaries of the agricultural drainage network, precipitation onto the lake surface, subsurface and groundwater inflow, as well as seawater input, and, on the other hand, governed by outputs, namely, outflow into sea and evaporation from the lake surface. Continuity equation, representing mass conservation, quantifies the change rate of stored water (S) within a lake system as the net difference between inflows and outflows:

$$\frac{\partial S}{\partial t} = Q_e + Q_d + Q_{\mathrm{gw}} + Q_{\mathrm{in}} + PA_s - EA_s - Q_{\mathrm{out}} \tag{1}$$

Where Q_e is effluent flow of point source from activities, Q_d is flow from drainage network discharging into the lake, Q_{gw} is flow from groundwater contribution, Q_{in} is inflow from sea, P is precipitation, A_s is surface area of the lake, E is losses by evaporation, Q_{out} is loss of water outflow from estuary.

Circulation in lakes is customarily driven by heat fluxes, wind stress, density currents, and tidal effect. Yet, net energy is to be conserved constant within the lake system, even though conversion in energy form is expected. Meanwhile, the total rate of change in a fluid property (W_p) with time (t), moving in x, y, and z directions with velocity components u, v, and w, respectively, can be followed as:

$$\frac{\mathrm{d}W_p}{\mathrm{d}t} = \frac{\partial W_p}{\partial t} + u\frac{\partial W_p}{\partial x} + v\frac{\partial W_p}{\partial y} + w\frac{\partial W_p}{\partial z} \tag{2}$$

Based on Newton's second law, momentum conservation is reflected by a change in momentum within the lake system, which is governed by forces such as pressure and acceleration of gravity and related to flow velocity and bathymetry. Mathematical formulation of this principle is found in several representations [14].

In application, assuming steady-state, well-mixed system is mostly considered, despite that changes throughout lake system are undeniable. Thomann and Mueller [16] argued that assumption of a well-mixed system for lakes as simplification can be justified to acquire an overall evaluation of system behavior, but should be acknowledged as an approximation to the actual state. However, assuming steady-state or well-mixed system within deltaic coastal lakes is hard to consider.

Characterizing hydrodynamics within coastal lakes is different from the well-established flowing pattern in the river system or systematic coastal regime. Understanding the complex structure within lakes, changes in flow velocity and direction, physical processes, biochemical interactions, inflows and tidal patterns, etc. requires the use of modeling. Models offer an effective way to address complicated processes simultaneously, as well as predicting response changes. Promising ready-to-use packages are now available to calibrate with a wide range of lake hydrodynamics and water quality conditions, e.g., Delft3D Software [17, 18].

In model application, numerous data are needed for a comprehensive system representation before simulating hydrodynamic processes within a lake. Necessary data for hydrodynamic modeling include measurements of tributary inflows and lake outflow rates, water quality and physical properties, bathymetry, as well as meteorological and hydrological data. However, data are customary faced by limitations [19]. Field data, if available, are mostly collected at low frequency and partial spatial coverage, not to mention lacking long-term observations. This fact highlights the role that remote sensing techniques offer to overcome the possible shortage in needed information.

2.3 Risks and Ability to Recover

Besides playing an essential role in the development process, lakes in the coastal region are expected to act as a natural adaptive measure to buffer potential climate change-related sea level rise. Yet, significant changes have been detected in structure and recovery functionality during recent decades and in an alarming rate. A prime concern is the water quality status of lakes. Deteriorating condition leads to compromised ecosystem that, in turn, endangers ecological health as well as socioeconomic benefits.

Usually, water bodies in nature have self-purification ability. But in the case of the deltaic coastal lakes, external effects exceed their assimilative capacity. Nutrient-driven vegetation and sedimentation build up hindered smooth circulation. With expanding islands and aquatic flora intensity, sediment accumulation pattern is redistributed. Sediment behavior (e.g., settling, resuspension, etc.) is governed by factors such as particle size, density current, and wind. Yet an overwhelming impact comes from flow velocity within lakes, inflows from irrigation-drainage network, and outlets connected to sea tidal action.

As drainage discharges with higher velocity enter lower energy impoundment of the lake, sediment tends to settle. Meanwhile, areas in close proximity to sea inlets experience direct effects of ebb/flow action. In either case, areas located further away are less affected by the changes at the confluence point neighbor zone, which create segments with different flow pattern, along with dispersion and mixing mechanism and, hence, water quality characteristics within the same lake. As a result, the declining trends are getting more complicated as time pass and discard the concept of self-recovery with the natural environmental cycle. Immediate management action is needed. However, dealing with established assets and local community requires certain sensibility and applicable approaches. Despite the need for fast response, the abrupt measure should be avoided.

3 Employing Remote Sensing Techniques in Tracking Transformation Pattern

3.1 Role of Satellite-Based Products in Change Monitoring

Decision making and planning for management action require multidisciplinary studies as well as extensive surveys. Data collection for analysis of changing features can be expensive, time-consuming, and even unfeasible, in certain locations, to carry out. Meanwhile, remote sensing techniques proved successful in several applications in land use and water science fields. This section investigates aspects in remote sensing potential for water quality monitoring within coastal lakes.

Launched Landsat 1 in the 1970s can be considered a starting point for a new level of remote observation of earth. Landsat 1, which was back then called "Earth Resources Technology Satellite," have had a multispectral scanner (MSS) detecting four separate spectral bands between 500 and 1,100 nm at 82 m resolution [20]. Ever since, the industry of advancing satellite specifications, and hence capabilities, offers improved temporal, spatial, and spectral resolutions.

Remotely sensed water quality status is mainly retrieved for parameters with optical reflective nature, e.g., turbidity, phytoplankton, suspended organic matters, etc. Yet indirect analyses are used to cover more water quality indicators, e.g., nutrient-related Nitrogen and Phosphorus contents. It should be noted that correlation with satellite imagery spectral characteristics not necessarily give exact concentrations [21], but offer enlightenment of trends and spatiotemporal distributions.

In Egypt, researchers have been addressing remote sensing-based water quality assessment, especially with the growing concerns of adverse effects of anthropogenic disturbance to environmental condition [1, 4, 6, 8, 10]. A most recent study by Rostom et al. [11] showed successful remote sensing-based heavy metal retrieval in Maruit Lake waters. For the purpose of demonstration, the following section intends to present an application of employing remote sensing to observe changes in water quality within an important coastal lake, namely, Burullus, which lately triggered many concerns.

3.2 *Case Study: Water Quality Indexing for Lake Burullus*

In an attempt to have a simple characterization of spatial variability within Lake Burullus, an index comprised of key indicators of water quality is developed.

3.2.1 Water Quality Index

Water quality is the principal indication of functionality and healthiness of an ecosystem. Water quality refers to the chemical, physical, and biological characteristics of the system water, and it has to be quantified with reference to the requirements of the desired beneficial uses. Water Quality Index (WQI) concept was initially developed by the National Sanitation Foundation during 1970 [22]. The effect of selective believed influensive, water quality parameters are combined in a single meaningful expression that reflects the water body quality state with respect to its uses. An expert panel was consulted for selecting quality parameters to consider in developed index. Recommended parameters for indexing were dissolved oxygen, fecal coliforms, pH, BOD, nitrate, phosphate, temperature, turbidity, total solids, toxic elements, and pesticides, with quality curves. As unequal effects were expected, significance weight (w_i) was allocated to each parameter quality (q_i), to be aggregated in an overall water quality index (WQI), (more details are found in [23])

$$\mathrm{WQI} = \sum_{i=1}^{n} w_i \ q_i \tag{3}$$

The concluded index is then scaled, categorized, and comparably judged based on intended beneficial use. While sharing a similar concept, several indices were then developed and applied for different condition and water uses. Commonly used is the WQI of the Canadian Council of Ministers of the Environment (CCME-WQI). The index is the result of combined measures of variance, namely, scope, frequency, and amplitude, which then categorize water quality from excellent to poor in six classes [24].

Application of indexing offers a means for defining a meaningful representative measure of the overall water quality state, in the form of a single number that simplify monitoring changes as well as following the effectiveness of management strategy. An advantage of WQI is that it facilitates communicating water quality conditions among all concerned parties, policy makers, nontechnical personnel, general public, etc. and not restricted water science profession [25].

3.2.2 Study Area

Lake Burullus is the second largest natural lake in Egypt located in north of the Nile delta east of Rosetta branch, along the Mediterranean coast, between longitudes 30°, 30′–31°, 10′E and latitudes 31°, 35′–31°, 21′N. The lake can be classified as shallow, mostly unstratified, with spatial difference in depth from 0.4 to 2.0 m. The deepest zone is sited in the western sector, which also has the lowest water salinity levels while, oppositely, the eastern sector is characterized as shallower and more saline [26]. Distinguished dual front is manifested in Lake Burullus, while connecting to the sea to the north through only one opening (Boghaz), branches of the irrigation-drainage network spread out along the lake boundary to the south, namely, Brimbal Canal, Drain 11, Drain 9, Drain 8, Drain 7, Nasser drain, Al-Gharbia drain, and El-Burullus drain (Fig. 3).

3.2.3 Selected Variables and Spectral Processing

This application follows the principal indexing concept, selecting representative parameters, and allocating weight to each parameter involved in WQI calculation according to its relative importance in the overall estimation. Accordingly, categorizing with reference to targeted beneficial purposes of the productive fishery and aquatic ecosystems, as well as healthy body contact recreational. In performing an assessment of water quality index for coastal Burullus Lake, variables related to key indicators that can be derived from satellite imageries were selected to be temperature, turbidity, and chlorophyll.

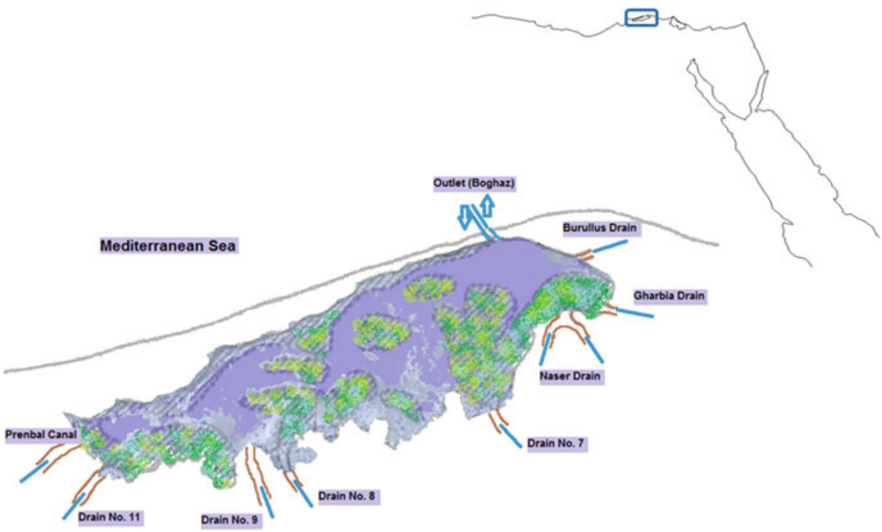

Fig. 3 Schematic of Burullus coastal lake

While dissolved oxygen (DO) is a vital indicator of water quality health and self-purification ability, yet it cannot be directly retrieved from satellite imageries. However, the temperature can be considered a reflective physical parameter of DO content. The increase in water temperature is customarily regarded as thermal pollution that negatively affects water quality status, aquatic ecosystem, and physical and biochemical processes. Raised temperature increases the metabolic rate of aquatic organisms and subsequently increases DO consumption. Moreover, like all gases, oxygen has decreased solubility in warmer water, which in turn reduces the oxygen concentration in water as temperature rise. Meanwhile, turbidity is considered an indication of optical properties of water that dictates the light penetration pattern and, hence, essential biochemical processes and natural process such as the ability of flora to photosynthesis to occur [27]. Chlorophyll-a content is selected to reflect nutrient existence and excessive growth of aquatic plants that would turn from beneficial to nuisance. The calculation of the WQI in this case study was done using weighted arithmetic water quality index (Eq. 3), giving the temperature 40% of the weight and turbidity and chlorophyll equal weight of 30% for each.

It is well-established that short wavelength of the spectrum has the stronger capability of water column penetration than longer wavelength [28]. Therefore, spectral bands of satellite image used for chlorophyll and turbidity derivation are those in the visible and near-infrared region of Landsat 8 imagery acquired in spring of the year 2015. Landsat 8 offers multispectral imageries sensed by both Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). Calculations of chlorophyll concentrations were based on early work by Akbar et al. [29] that has shown a strong relationship with band ratio of blue to red bands. Meanwhile, turbidity was derived following recent study findings [30] that concluded acceptable accuracy for developed algorism relating turbidity to the natural logarithm of red band and band ratio of blue and red. Surface temperature extraction from remote sensing product is deducted using thermal bands of the Landsat images. Transformation of thermal radiance image at surface temperature was deducted using imagery metadata information.

3.2.4 Result Analysis: WQI

For retrieving water quality-related properties within the lake, islands were masked out, and only water area was considered. Results show that higher turbidity is found in the eastern zone of the lake (Fig. 4), whereas chlorophyll-a exists at the highest level in the west of the lake, which coincide with raised temperature grades, as demonstrated in Figs. 5 and 6, respectively. Aggregated Water Quality Index within the lake is illustrated in Fig. 7. Notably, results show good agreement of concluded WQI trend with actual observations to a great extent. According to findings, it can be concluded that remote sensing of selective parameters would give a sensible idea of tendency and spatial difference within a lake with such multi-aspect interactions. Therefore, the potential of remote sensing techniques for monitoring and management is worth considering in further applications. It should be emphasized,

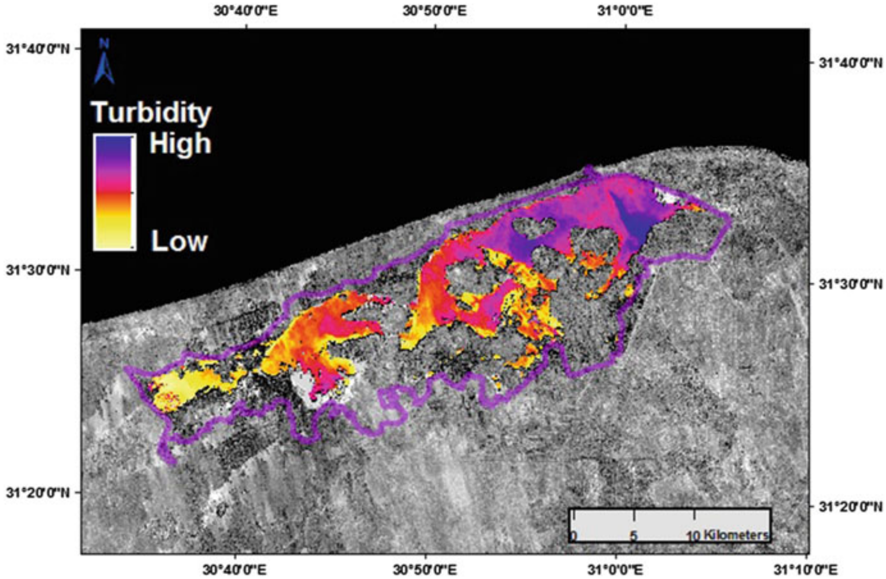

Fig. 4 Remotely sensed turbidity trend within Lake Burullus in spring 2015

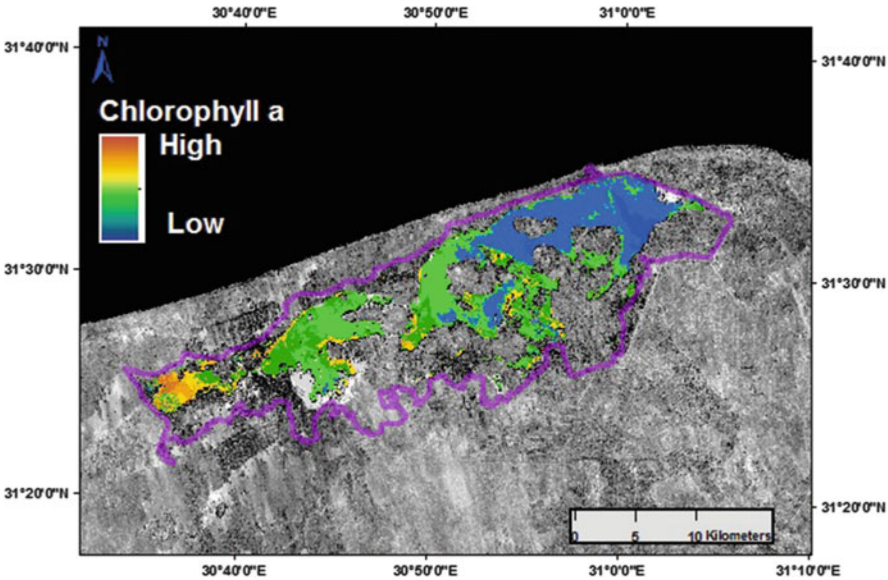

Fig. 5 Remotely sensed chlorophyll-a trend within Lake Burullus in spring 2015

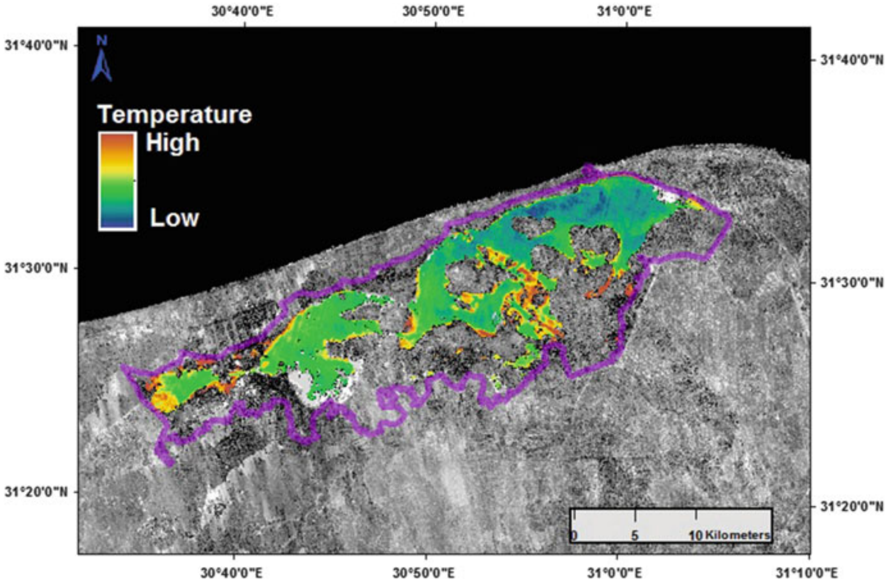

Fig. 6 Remotely sensed thermal trend within Lake Burullus in spring 2015

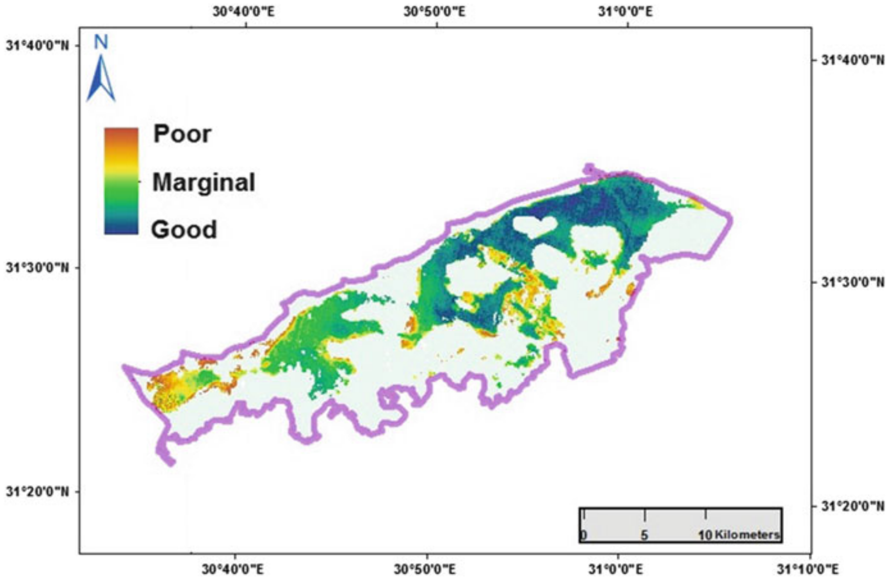

Fig. 7 Water quality index in Lake Burullus, spring 2015

however, that the main purpose of using WQI in this case study is to get initial representative quality trend within the lake under consideration, using simple methodology. Advanced application including more water quality parameters, accompanied with ground truth measurements, is recommended to obtain more detailed information.

4 Strategy for Coastal Lake Restoration

4.1 Proposed Management Strategies

Keeping steady balanced ecosystem while aggressively moving ahead in development processes is a dilemma that concerns many parties, environment advocates, energy expert, natural resources managers, and decision makers. Threats involving resource depletion and socioeconomic instability have encouraged a number of studies to investigate causes and possible remedial actions. It was widely established that major part of the coastal lake problems is caused by increasing municipal, agricultural, and industrial discharges. Drained wastewaters into the lakes considerably changed nutrient and salinity levels within that, in turn, negatively affected aquatic species structure and population density. Consequent disturbance in hydrodynamics and sediment transport pattern hindered smooth circulation and, hence, reflected harmfully on water quality condition within the lakes.

The perfect corrective strategy would be targeting comprehensive restoration to the former healthy environmental system of coastal lakes. This would entail lessening nutrient-loaded freshwater inputs while increasing exchange rate with seawater, preserving acceptable water quality condition that meets the stipulated environmental laws, as well as ensuring functional water flow and circulation mechanism that prevent sedimentation and allow active self-purification. Therefore, suggested measures to be considered are:

- Add outlet (Boghaz) for more seawater exchange.
- Lessen incoming discharges from irrigation-drainage network through redirection of drainage flow with alarming quality condition.
- Strictly enforce, and update stipulated regulations with discharging facilities.
- Manipulate flow velocity within lakes.
- Perform more frequent dredging and reed removal, as well as deepen lake bed levels, e.g., ray streams.
- Stop drying and earth-filling invading into lake water surface.
- And, to be addressed with integrated viewpoint, coastal lakes restoration should be mainstreamed within the Integrated Coastal Zone Management (ICZM).

However, sensibility in finding an effective strategy that helps regain productive, environmentally safe coastal lake dictates acceptance to inevitable sacrifices. Also, and despite the need for immediate response, it should be recognized that swift application is not expected.

4.2 Reasoning Challenges, Effectiveness, and Adaptability

The right to develop and benefit from resources to get a better life cannot be denied, yet adverse effect comes right back hitting strongly. Obviously, established assets and ongoing activities cannot be stopped abruptly. Concepts such as instant decrease of wastewater effluent rate discharged into coastal lakes, or even aspire to have perfect pre-discharge treatment in a developing country that already struggles in many areas, are unachievable. Therefore, management strategy should be designed with gradual application plan, while avoiding complex measures.

It is important to acknowledge the advantage of coordination among concerned parties. Collaborative efforts with effective communication mechanism would avoid conflict or repeated works. An additional benefit would be gained by raising awareness of local communities and ensure smooth information exchange. Last but not least, with the inherited issue of insufficient data coverage, benefit from the ever-advancing earth observation and remote sensing techniques would help filling data gaps and to have more spatial and temporal observation records.

5 Conclusions and Recommendations

Being an essential source for fish production, recreational and flood control potential gave the coastal lakes of Egypt a treasured status. Coastal lake in the Nile delta region is a meeting point for different types of water properties, affected by coastal characteristics and development processes in served watershed. For decades, coastal lakes have alleviated polluting impact reaching the Mediterranean Sea. Yet multiple sources of wastewater released, e.g., agricultural, industrial, and municipal, beside discharges from expanding fish farms, all contribute to dramatic alteration in salinity and nutrient levels within coastal lakes. Changes in aquatic biota structure, dense plants, as well as drying and earth-filling practices shift dynamic patterns of flow velocity, circulation behavior, and sedimentation tendency.

Maintaining functional ecosystem condition in coastal lakes of Egypt with ever-expanding development activities is a challenge. Footprints of the progressive development processes are undeniably beating natural ability for self-purification and fast recovery of those water bodies. Therefore, comprehensive management strategy is due.

Reaching educated decision for managerial measures, with multidisciplinary nature, should be backed with detailed information of well-monitored lake system. Yet reference data are not always available as extensively as required. Advances in earth observation field are expected to provide a boost to data collection and monitoring processes. Among the benefits of introducing remote sensing techniques in coastal lake management is the vast pool of data offered, with more frequent interval and expanded spatial coverage. Beside possible establishment of a historical database, analyzed satellite imageries would also facilitate regular monitoring for key management indicators. Potentiality of remote sensing in the field of water resources management and quality monitoring was addressed, through a case study application. Processed earth observation satellite imageries proved liable in reflecting the spatial change of key water quality features in the Burullus coastal lake.

While pursuing an integrated management plan, it is important to establish effective networking, information exchange, and coordination among concerned parties. Also, a useful act to consider is to raise awareness; communicate lake conditions and risks ahead to the public in order to gain their support, and cooperation.

Finally, it is recommended to incorporate modeling techniques in further studies to reach a gradual restoration of deltaic coastal. Modeling scenarios facilitate investigating several concerns simultaneously, checking alternate managerial measures, and then following potential success and, hence, optimum selection to be adopted.

References

1. Abayazid H (2015) Assessment of temporal and spatial alteration in coastal lakes – Egypt. In: Proceedings of the eighteenth International Water Technology Conference 2015 (IWTC 2015), Sharm El Sheikh, 12–14 Mar 2015, pp 598–608
2. Abayazid H, Al-Shinnawy I (2012) Coastal lake sustainability: threats and opportunities with climate change. J Mech Civil Eng Int Organ Sci Res (JMCE/IOSR) 1(5):33–41
3. Ahmed S, Kaiser M (2014) Monitoring water pollution of lake mariout on the Mediterranean coast of Egypt. Int J Remote Sens Appl 4(1):36–40. https://doi.org/10.14355/ijrsa.0401.03
4. Dewidar K, Khedr AA (2005) Remote sensing of water quality for Burullus Lake, Egypt. Geocarto Int 20(3):43–49
5. The Egyptian Environment Affairs Agency (EEAA) (2003) Al-Burullus wetland's hydrological study. Natural Protectorates Central Administration Press, pp 1–18
6. El-Kafrawy SB, Khalafallah A, Omar M, Khalil MMH, Yehia A, Allam M (2015) An integrated field and remote sensing approach for water quality mapping of Lake Burullus, Egypt. Int J Environ Sci Eng (IJESE) 6:15–20
7. Farag H, El-Gamal A (2012) Assessment of the eutrophic status of Lake Burullus (Egypt) using remote sensing. Int J Environ Sci Eng (IJESE) 2:61–74
8. Hereher ME, Salem MI, Darwish DH (2010) Mapping water quality of Burullus lagoon using remote sensing and geographic information system. J Am Sci 7(1):138–143
9. El-Adawy A, Negm AM, Elzeir MA, Saavedra OC, El-Shinnawy IA, Nadaoka K (2013) Modeling the hydrodynamics and salinity of el-Burullus Lake (Nile Delta, northern Egypt). J Clean Energy Technol 1(2):157–163
10. Saad El-Din M, Gaber A, Koch M, Ahmed RS, Bahgat I (2013) Remote sensing application for water quality assessment in Lake Timsah, Suez Canal, Egypt. J Remote Sens Technol 1 (3):61–74
11. Rostom NG, Shalaby AA, Issa YM, Afifi AA (2017) Evaluation of Mariut Lake water quality using hyperspectral remote sensing and laboratory works. Egypt J Remote Sens Space Sci 20 (Suppl 1):S39–S48
12. Embabi NS, Moawad MB (2014) A semi-automated approach for mapping geomorphology of el Bardawil Lake, northern Sinai, Egypt, using integrated remote sensing and GIS techniques. Egypt J Remote Sens Space Sci 17:41–60
13. Anderson JD (2007) Fundamentals of aerodynamics4th edn. McGraw-Hill, New York
14. Brutsaert W (2005) Hydrology – an introduction. Cambridge University Press, New York

15. Chapra SC (1997) Surface water-quality modeling. McGraw-Hill, New York
16. Thomann RV, Mueller JA (1987) Principles of surface water quality modeling and control. HarperCollins, New York
17. Deltares (2011) Delft3D-FLOW: simulation of multi-dimensional hydrodynamics flows and transport phenomena, including sediments. User manual version 3.15. Deltares, Delft
18. Donia N, Bahgat M (2016) Water quality management for Lake Mariout. Ain Shams Eng J 7:527–541
19. Jones HFE, Hamilton DP (2014) Hydrodynamic modelling of Lake Whangape and Lake Waahi. Waikato Regional Council technical report 2014/24
20. Chang N, Imen S, Vannah B (2015) Remote sensing for monitoring surface water quality status and ecosystem state in relation to the nutrient cycle: a 40-year perspective. Crit Rev Environ Sci Technol 45:101–166
21. Wu C, Wu J, Qi J, Zhang L, Huang H, Lou L, Chen Y (2010) Empirical estimation of total phosphorous concentration in the mainstream of the Qiantang River in China using landsat TM data. Int J Remote Sens 31(9):2309–2324
22. Brown RM, McClelland NI, Deininger RA, O'Connor MF (1972) A water quality index crashing the psychological barrier. Indicators Environ Qual 1(1):173–178
23. Brown RM, McClelland NI, Deininger RA, Tozer RG (1970) A water quality index – do we dare? In: National symposium on data and instrumentation for water quality management & water and sewage works
24. Canadian Council of Ministers of the Environment (CCME) (2001) Canadian Water Quality Index 1.0 technical report and user's manual. Canadian environmental Quality Guidelines Water Quality Index Technical Subcommittee, Gatineau
25. Stoner JD (1978) Water-quality indices for specific water uses. Geol Surv Circ 770:1–12
26. Doumont H, El-Shabrawy G (2007) Lake Burullus of the Nile Delta: a short history and uncertain future. R Swed Acad Sci Ambio 36(8):677–682
27. Perrie SM, Milne JR, Greenfield S (2012) Greater Wellington Regional Council, Environmental Monitoring and Investigations Department, GW/EMI-T-pp.12/143. ISBN: 978-1-927217-13-9 (online)
28. Liu Y, Islam MA, Gao J (2003) Quantification of shallow water quality parameters by means of remote sensing. Prog Phys Geogr 27(1):24–43
29. Akbar T, Hassan Q, Achari G (2010) A remote sensing based framework for predicting water quality of different source waters. Int Arch Photogramm Remote Sens Spat Inf Sci 34. Part XXX
30. Abayazid H, El-Gamal A (2017) Employing remote sensing for water clarity monitoring in the Nile Delta Coast. IWTJ, IAWT. (in press)