ANALYSIS OF BURULLUS WETLAND ECOSYSTEM USING DPSIR FRAMEWORK

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ABSTRACT

Sustainable management of wetlands ecosystem become a serious crucial, especially with the rapid population growth and increase of anthropogenic activities, in addition to climate change threats. Several approaches have been introduced for ecosystem analysis and management since 1990s, where Driver – Pressure – State – Impact – Response (DPSIR) framework is one of the widely used approaches for assessing and managing environmental problems. This study applied DPSIR framework on Burullus wetland as a model of Egyptian Northern ecosystems, in order to analyze it from the perspective of its potential to deliver ecosystem services within current state of changes resulted from socio-economic drivers. Such changes have a direct or indirect impact on the wetland health and productivity, thus distress local communities relay on its services. Five main socio-economic drivers were analyzed and introduced through DPSIR framework. Number of actions and responses were recommended depending on DPSIR framework analysis. The results of this study will guide to prepare a management and restoration plan for Burullus wetland based on ecosystem approach.

Keywords: Driver, Pressure, State, Impact, Responses, DPSIR, Ecosystem Services, Burullus wetland, Restoration

Abbreviations:

IBA	Important Birds Area
DPSIR	Driver - Pressure - State of Change - Impact - Response

EEA	European Environment Agency
RS	Remote Sensing
SLR	Sea Level Rise
LU/LC	Land use/ Land cover

INTRODUCTION

Wetlands are one of the most unique and productive worldwide ecosystems where terrestrial and aquatic habitats meet. They play a critical role in sustaining many natural cycles and supporting a wide range of biodiversity. Almost all of the world's water birds use wetlands as a feeding and breeding grounds. They also have vital recreational, historical, scientific and cultural values (UNEP, 2015).

Burullus wetland is the second-largest wetland in Egypt, located in the central part of the Northern section of the Nile Delta. It was declared a wetland nature reserve under the international Ramsar convention and a national protectorate in 1998 (Khedr & Lovett-Doust, 2000). It offers a wide diversity of various habitats ranging from water fresh swamps, to salt marshes and mudflats. The shores and islets of the wetland comprise one of the most important reed beds in the Mediterranean region, where this type of habitat is becoming rare and threatened (Shaltout, 2017).

However, Northern wetlands in the Nile Delta of Egypt are recently under threats of anthropogenic stresses caused by the accelerated population growth (El-Asmar, Hereher, & El-Kafrawy, 2012), coupled with unplanned developing activities that led to urbanization, posing serious implication on its current resources (Hegazy & Kaloop, 2015). In addition to pollution from drainage water that discharge a huge amount of wastes enriched with

agricultural fertilizers, industrial and sewage effluents. These conditions affected directly and/ or indirectly water quality of the wetland, causing eutrophication state (Okbah & Hussein, 2005).

The increase of human pressures and consequent loss of wetlands need more efforts to conserve, where habitat conservation in terms of quantity and quality is a first priority (Khedr & Lovett-Doust, 2000). Although assessing the link between human pressures and state-changes in marine and coastal ecosystems remain a challenge, there are several conceptual frameworks for describing these links (Patrício et al., 2016). Drivers - Pressures - State - Impact - Responses (DPSIR) framework is one of the developed approaches that widely adopted to understand human causes of environmental degradation (Kristensen, 2004), DPSIR is a mean of structuring and analyzing information in decision-making across ecosystems (Patrício et al., 2016).

The objective of the present study is to analyze the state of Burullus wetland ecosystem within the recent pressures exerted from socio-economic drivers and to recommend a number of responses and actions needed to manage and restore the wetland to its natural condition when declared a protectorate in 1998.

METHODOLOGY

DPSIR framework was prepared based on understanding the interaction between socio-economic developments as a “Drivers” which exert or mitigate pressures on the environment. Such “Pressures” cause stresses on environmental status. “State” of environment change present its condition in terms of quantity and quality of resources. “Impacts” describe the effect of

the changed environment and its consequences on human health and economy (Smeets & Weterings, 1999). Accordingly, a number of "Responses" are recommended as a feedback loop to mitigate the environmental changes as shown in Figure (1).

State of change of Burullus wetland was assessed through an integrated overview of its provisional economic services, water quality status, land use change and their interactions. Set of indicators were addressed identifying the impact of exerted pressures on the wetland natural conditions. A number of responses were recommended to guide in preparation of integrated management and restoration plan based on ecosystem approach, as shown in Figure (2). The data was collected from different sources, including literature review, several field visits to selected villages of the five districts surrounding the wetland, direct interview of a number of relevant stakeholders. Besides, two questionnaires were prepared, fulfilled and analyzed. The first was questionnaire focusing on socio-economic and gender aspects, while the other focus on detailed economic valuation of the wetland's provisional ecosystem services.

DESCRIPTION OF THE WETLAND ECOSYSTEM AND SERVICES

The study area includes Burullus wetland and the five adminstrave districts surrounding it; Baltim, El-Hamoul, El-Riad, Sidisalem and Motobas.

1- Site Description: Burullus is one of the most vulnerable Egyptian wetlands along the Mediterranean coast. It is situated at the north central part of the Delta between 30° 30' and 31' 10'E and latitudes 31° 19' and 31' 36'N. The wetland is located between the two Nile River branches: Damietta and

Rosetta, in Kafr El Sheikh Governorate as shown in (Figure 3) (Attia, 1992). It is a shallow brackish water wetland with an average depth of 115 cm. The wetland receives most of its water at its southern margins through agricultural drains. Besides, Brimbal Canal at the western part of the wetland and Mediterranean sea through a small opening called Boughaz EI-Burullus (Samaan et al., 1989). The wetland is rich of a variety of rare plants, animals and aquatic life as well as its special geographical nature used by migratory birds (Abayazid & Al-Shinnawy, 2012).

2- Current Ecosystem Services: Burullus wetland offers several provisional, regulating, recreational ecosystem services. From analyzed questionnaires, it was clear that fishery and agriculture activities are considered the most important activities for local communities. The other activities include: reed harvesting, grazing, bird hunting, gathering economic plants and salt extraction with only a small minority working in fishery complementary industries e.g. boats industry. Economic activities in each district depend mainly on the available ecosystem services as shown in Table (1).

Table(1): Main activities in main districts around Burullus wetland

District	Fishing	Fishing Industry	Fish Farming	Agriculture	Grazing	Salt Extraction	Reed Harvesting
Burullus	√	√		√	√	√	√
Sidisalem	√	√		√	√		
El Hamoul	√		√				
El Reyad	√			√	√		
Motobas	√	√	√	√	√		

RESULTS AND DISCUSSIONS

The main components of DPSIR framework can be analyzed as following

1) **Socio-Economic Drivers:** The wetland ecosystem is affected by several socio-economic drivers resulting from rapid population growth and urbanization expansion which recently stresses its economic resources (Farag, 2011). The lowers lands at the southern boundary of the wetland have been extensively utilized by local communities for agriculture purposes; some of these low- level areas had been converted into fish farms due to its profitability (Asmar et al., 2013). Besides, the accelerated impact of sea level rise (SLR), with the subsidence of the Delta itself which makes the region one of the most vulnerable areas in the world (Zingstra, 2013). Most of these hazards are human-induced, except Delta subsidence and SLR that belong to the natural hazards (Asmar et al., 2012).
2) **Main Environmental Pressures:** The main pressures exerted from the above discussed drivers can summarized as follows:

A- Increase Of Drainage Discharge: Population growth, expansion of agricultural and industrial activities around the wetland led to huge amount of daily bypassing of untreated or partially treated sewage, industrial and uncontrolled agricultural waste water through water fresh drainage channels discharging into the wetland. Most of agricultural drainage water of middle Nile Delta is discharged in the wetland, where its southern side receives drainage water from agricultural drains (11, 9, 8, 7, Nasser and

El-Gharbia) as shown in Figure (4). The total drainage discharged into the wetland is 3904 million m3/year (Zeiny & Kafrawy, 2017).

B- Climate Change Threats: Burullus wetland is highly vulnerable to climate change threats, due to temperature increases and sea level rise (SLR) threats. Possibilities of the wetland to mitigate SLR have decreased as a result of increasing discharged water into the wetland, causing a higher water level. Although sand dunes along the northern part naturally protect low lying area from SLR and salt intrusion of agriculture lands around the wetland, they are heavily threatened by erosion from anthropogenic activities (Asmar et al., 2012).

C- Unsustainable Fishing: Fish farming become a widespread activity along the southern shores of Burullus wetland since 1984 and recently increased along the northern shore, due to its higher profitability than agriculture (Figure 5). Part of that profitability is achieved by stocking of fry caught illegally at the inlet (El-Shinnawy, 2002). Overfishing of fry from the wetland has a substantial negative impact on fish stocks available for the fishermen and local markets. Rare species of amphibians and plants have been disappeared due to the creation of fish farm ponds (Zingstra, 2013).

3) State Change And Impact : Some indicators were proposed for assessing the changes in the wetland conditions and their impact on its health.

A- Land Use/ Land Cover Change From 1998 To 2015: Changes in land use/land cover (LU/LC) around the wetland, unwise urban development and construction of international high way that cuts through the northern sand bar, negatively affected its ecosystem. These changes impact socio-

economic, biological, climatic and hydrological systems. A recent study compared LU/LC change of Burullus wetland from 1998 to 2015 using RS technique, clarified that the wetland is subjected to reduction in its area and sand bar by 22.8%, 8.5% respectively with increase in floating vegetation and surrounded agriculture land by 17.9%, 9.7% respectively (Hossena & Negm, 2016), as shown in Figure (6).

B- Water Quality: Burullus wetland is one of the vulnerable ecosystems that suffers from dense blue green algae caused mainly by expansion of fish farming, agriculture activities, increasing fertilizers and pesticides concentration. Besides, the sediment pollution that contribute to water pollution of the wetland (Ali, 2011). The levels of pollution was classified into high (15%) in the south, south western part and along the wetland shore lines which are most affected areas by human activities. Moderate (73%) in the center of the wetland, where the anthropogenic activities decrease and typically the pollution is diluted and low (12%) in the extreme north and in the core of the wetland (Zeiny & Kafrawy, 2017).

C- Fish Quality And Quantity: Although annual fish statistics stated that total fish production of the wetland has reached 65,066 ton in 2015 (GAFRD, 2015), recently the amount of freshwater species have increased in comparison with marine species (more profitable) due to the decrease of sea water entering the wetland and increase of fresh water discharging from agriculture drainage as shown in Figure (7).

4) Stakeholder's Responsibilities: Identifying stakeholder's importance is an essential step for ensuring integrated management and preventing

responsibilities overlap. Four categories were fulfilled according to Burullus wetland status. However, category IV is not effective in the wetland management as shown in Tables 2 and 3.

Table(2): Stakeholders Categorization (IUCN, 2014)

Category I: High importance, Low influences	Category II: High importance, High influence
Category IV: Low importance, Low influence	Category III: Low importance, High influence

Table(3): Stakeholders of Burullus wetland Identification

Category I	Category II	Category III
Primary stakeholders	Key stakeholders	Secondary stakeholders
Depend directly on natural resources	Significantly influence any chosen intervention in the environment	Do not depend directly on the natural resources/ have a major interest in the way wetland is managed
Fishermen Aquaculture farmers Agriculture farmers Bird hunters	Governorate Ministry of Water Resources Ministry of Housing Ministry of Defense Ministry of Health EEAA Ministry of Agriculture Ministry of Interior	NGOs Fishermen associations Fishermen Chief Universities and Research institutions Religious groups Agriculture associations

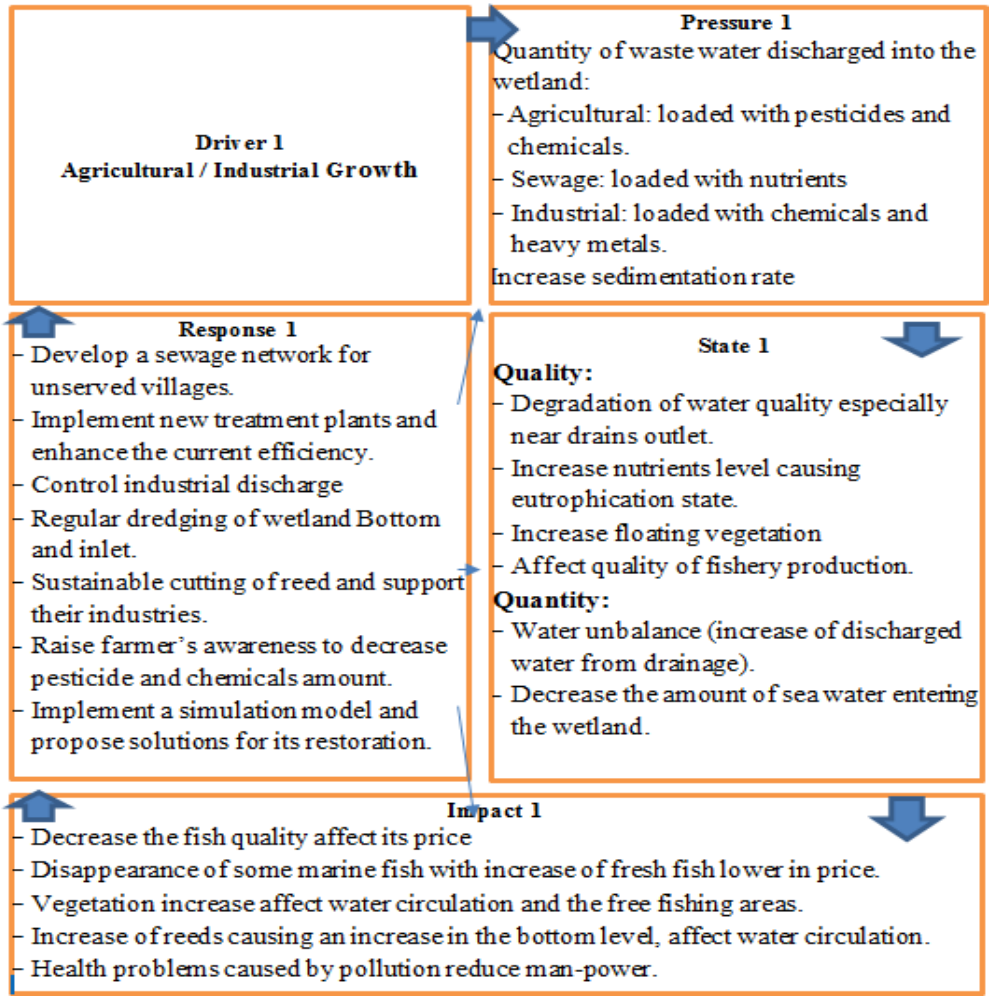
DPSIR ANALYSIS

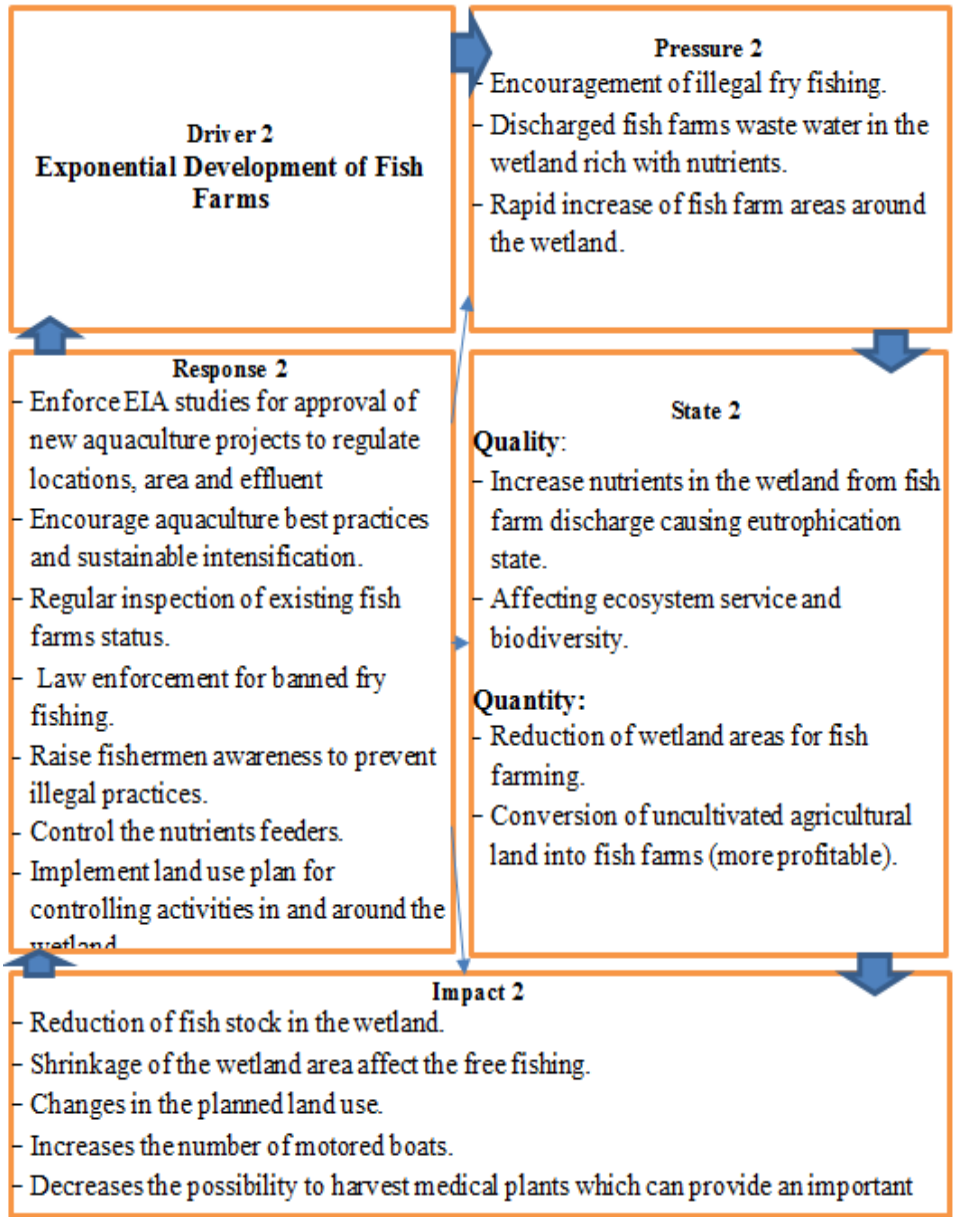
DPSIR framework was analyzed using a chain of causal links according to the main anthropogenic drivers discussed above; agricultural/industrial growth, expansion of fish farms, population growth and stakeholder's interest, while climate change is considered one of the natural drivers.

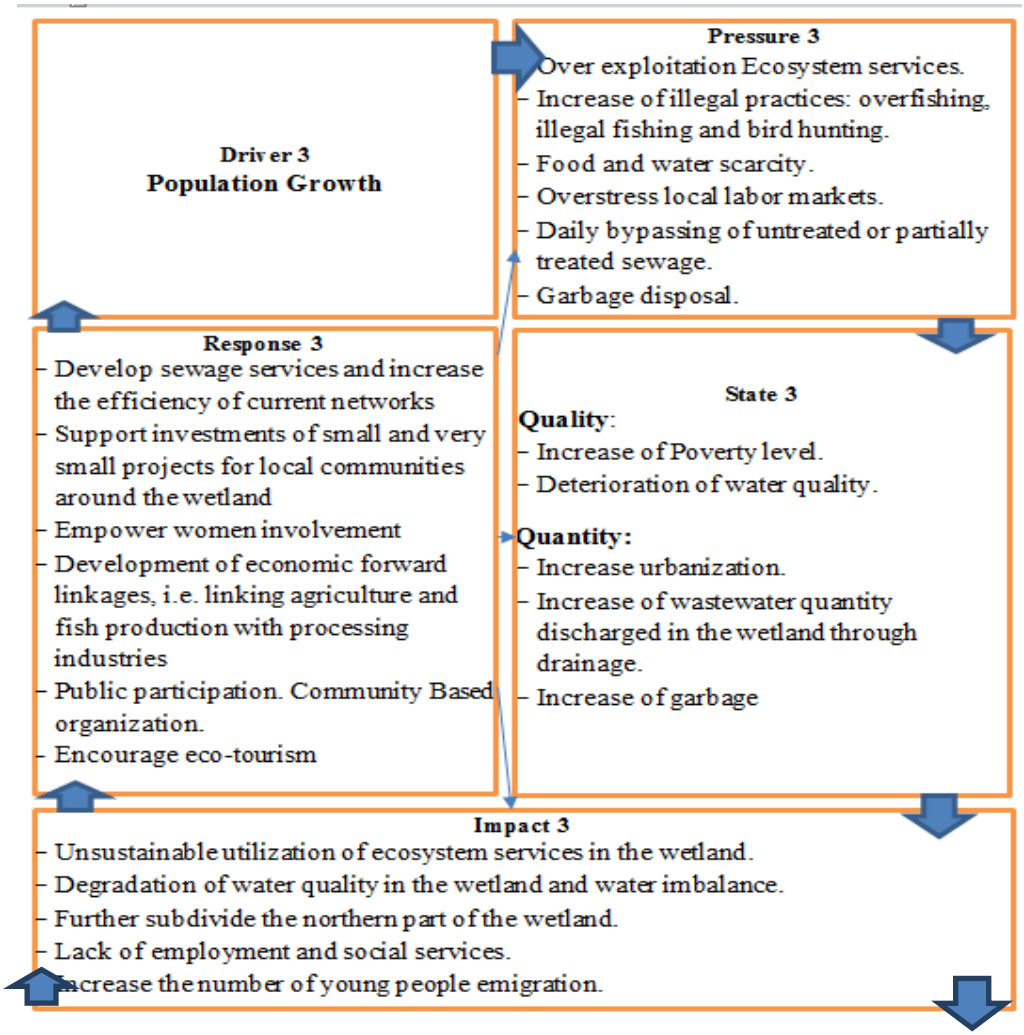
Pressures exerted on the wetland ecosystem and community's economy affected by its degradation were identified. State of change was analyzed in the prospective of quality and quantity that impact the ecosystem functions

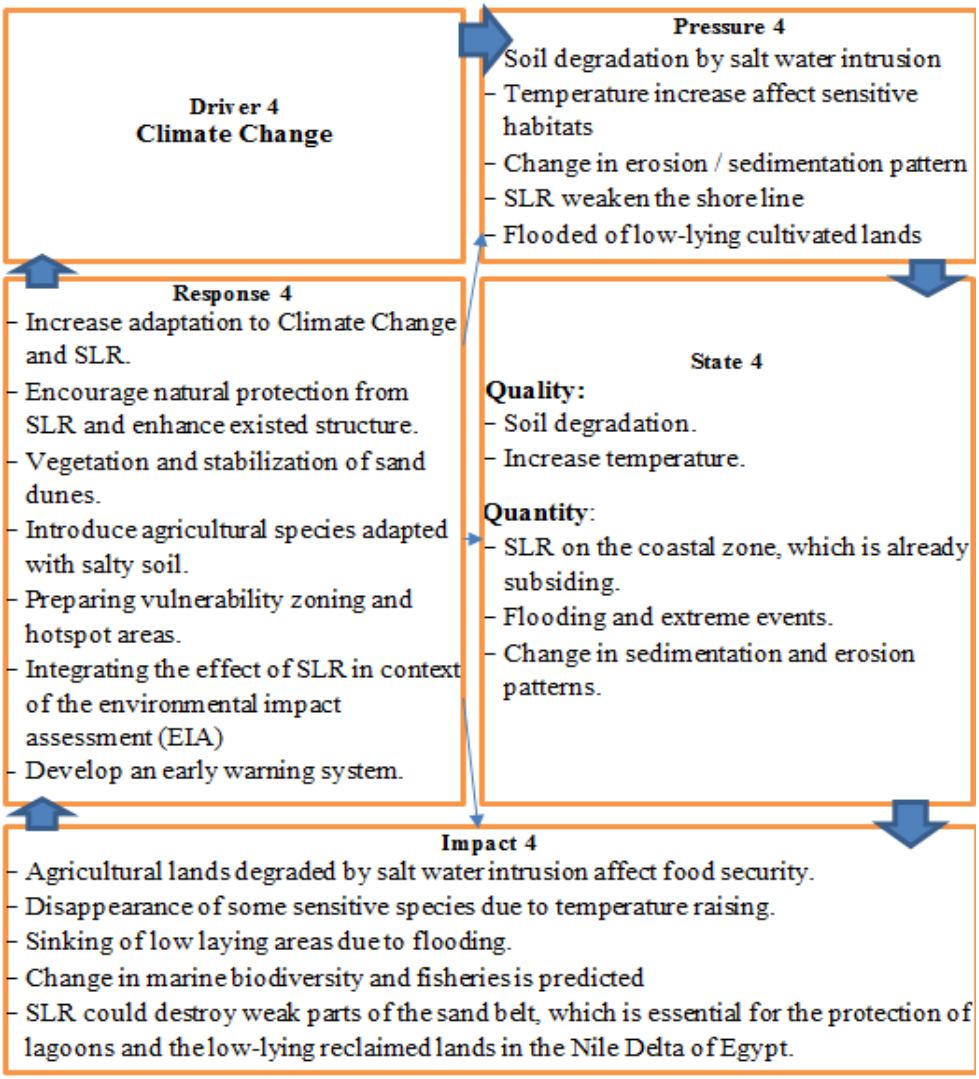
and human health. Required responses to mitigate the exerted pressures were recommended as short term management and restoration plan and long term strategies needed to improve the wetland status (Figure 8).

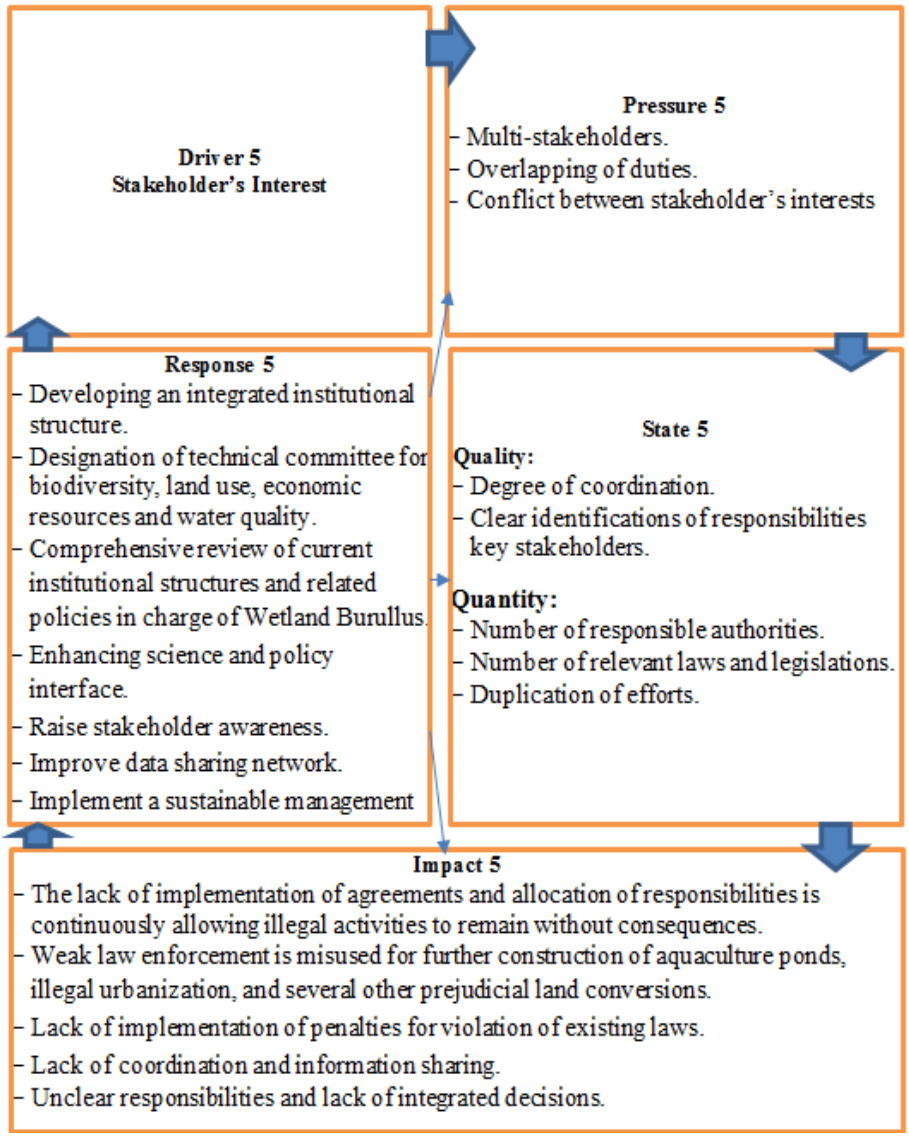
The next section shows DPSIR framework analysis for each proposed driver, results and recommendations through numbers of political responses that are needed to restore the wetland ecosystem.




Driver 2
Exponential Development of Fish Farms
Pressure 2
- Encouragement of illegal fry fishing.
- Discharged fish farms waste water in the wetland rich with nutrients.
- Rapid increase of fish farm areas around the wetland.
Response 2
- Enforce EIA studies for approval of new aquaculture projects to regulate locations, area and effluent
- Encourage aquaculture best practices and sustainable intensification.
- Regular inspection of existing fish farms status.
- Law enforcement for banned fry fishing.
- Raise fishermen awareness to prevent illegal practices.
- Control the nutrients feeders.
- Implement land use plan for controlling activities in and around the wetland
State 2
Quality:
- Increase nutrients in the wetland from fish farm discharge causing eutrophication state.
- Affecting ecosystem service and biodiversity.
Quantity:
- Reduction of wetland areas for fish farming.
- Conversion of uncultivated agricultural land into fish farms (more profitable).
Impact 2
- Reduction of fish stock in the wetland.
- Shrinkage of the wetland area affect the free fishing.
- Changes in the planned land use.
- Increases the number of motored boats.
- Decreases the possibility to harvest medical plants which can provide an important


Driver 3
Population Growth
Pressure 3
- Over exploitation Ecosystem services.
- Increase of illegal practices: overfishing, illegal fishing and bird hunting.
- Food and water scarcity.
- Overstress local labor markets.
- Daily bypassing of untreated or partially treated sewage.
- Garbage disposal.
State 3
Quality:
- Increase of Poverty level.
- Deterioration of water quality.
Quantity:
- Increase urbanization.
- Increase of wastewater quantity discharged in the wetland through drainage.
- Increase of garbage
Response 3
- Develop sewage services and increase the efficiency of current networks
- Support investments of small and very small projects for local communities around the wetland
- Empower women involvement
- Development of economic forward linkages, i.e. linking agriculture and fish production with processing industries
- Public participation. Community Based organization.
- Encourage eco-tourism
Impact 3
- Unsustainable utilization of ecosystem services in the wetland.
- Degradation of water quality in the wetland and water imbalance.
- Further subdivide the northern part of the wetland.
- Lack of employment and social services.
- Increase the number of young people emigration.


Driver 4
Climate Change
Pressure 4
Soil degradation by salt water intrusion
Temperature increase affect sensitive habitats
Change in erosion / sedimentation pattern
SLR weaken the shore line
Flooded of low-lying cultivated lands
Response 4
Increase adaptation to Climate Change and SLR.
Encourage natural protection from SLR and enhance existed structure.
Vegetation and stabilization of sand dunes.
Introduce agricultural species adapted with salty soil.
Preparing vulnerability zoning and hotspot areas.
Integrating the effect of SLR in context of the environmental impact assessment (EIA)
Develop an early warning system.
State 4
Quality:
Soil degradation.
Increase temperature.
Quantity:
SLR on the coastal zone, which is already subsiding.
Flooding and extreme events.
Change in sedimentation and erosion patterns.
Impact 4
Agricultural lands degraded by salt water intrusion affect food security.
Disappearance of some sensitive species due to temperature raising.
Sinking of low laying areas due to flooding.
Change in marine biodiversity and fisheries is predicted
SLR could destroy weak parts of the sand belt, which is essential for the protection of lagoons and the low-lying reclaimed lands in the Nile Delta of Egypt.


Driver 5
Stakeholder's Interest
Pressure 5
- Multi-stakeholders.
- Overlapping of duties.
- Conflict between stakeholder's interests
Response 5
- Developing an integrated institutional structure.
- Designation of technical committee for biodiversity, land use, economic resources and water quality.
- Comprehensive review of current institutional structures and related policies in charge of Wetland Burullus.
- Enhancing science and policy interface.
- Raise stakeholder awareness.
- Improve data sharing network.
- Implement a sustainable management
State 5
Quality:
- Degree of coordination.
- Clear identifications of responsibilities key stakeholders.
Quantity:
- Number of responsible authorities.
- Number of relevant laws and legislations.
- Duplication of efforts.
Impact 5
- The lack of implementation of agreements and allocation of responsibilities is continuously allowing illegal activities to remain without consequences.
- Weak law enforcement is misused for further construction of aquaculture ponds, illegal urbanization, and several other prejudicial land conversions.
- Lack of implementation of penalties for violation of existing laws.
- Lack of coordination and information sharing.
- Unclear responsibilities and lack of integrated decisions.

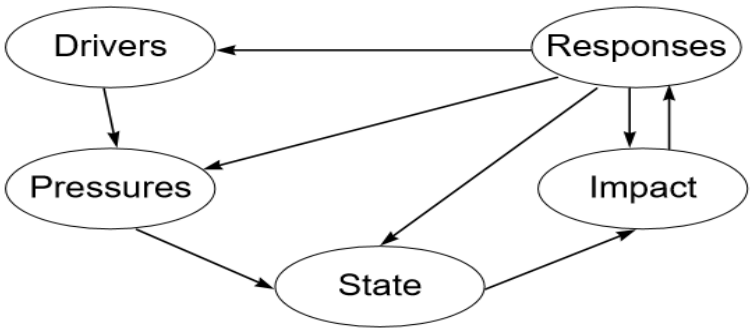
Dpsir Framework Clarifies The Following:

- Main drivers affecting the wetland ecosystem services are agricultural and industrial growth, population growth, climate change, exponential development of fish farms and Stakeholders interests.
- The wetland receives drainage water that carry accumulated wastewater from agricultural activities loaded with pesticides and chemicals, industrial loaded with chemicals and heavy metals and sewage loaded with nutrients, affecting water quality and lead to eutrophication conditions in some parts of the wetland.
- The increase discharge of drainage water affects the amount of sea water entering the wetland through the inlet. Thus, affecting the water quality and sediment level in the wetland.
- Exponential development of fish farms change the land use, encourage illegal fry fishing and increase nutrient level in the wetland due to discharging of their waste water into the wetland.
- Area reduction is mainly attributed to the reclamation and drying processes of the fish ponds mainly in the South and East parts of Burullus region.
- Sea level rise, salt water intrusion and temperature increase resulting from climate change threats the wetland ecosystem and habitats.
- Multi-stakeholders, overlapping of duties and conflict between stakeholder's interests affect the management procedures.

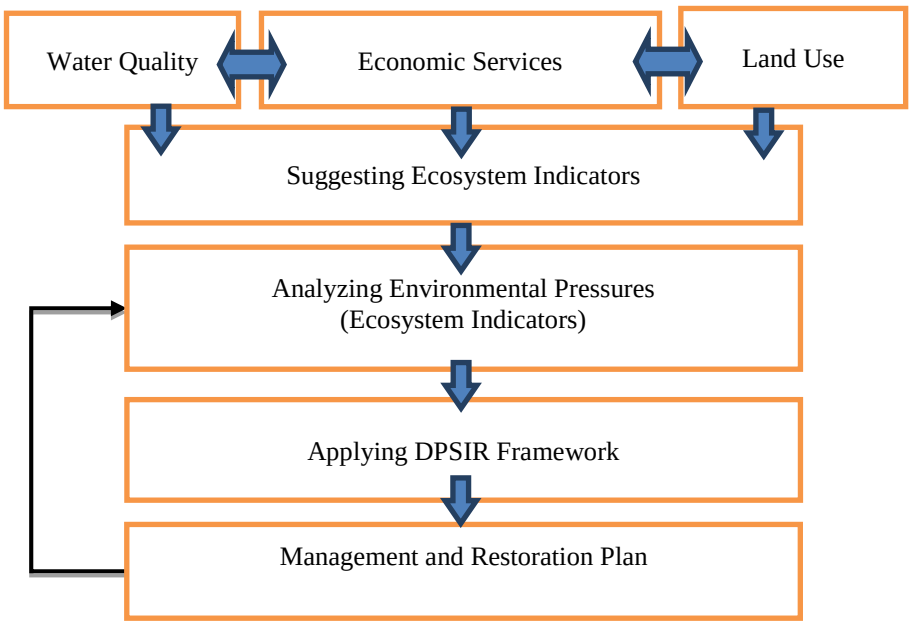
Dpsir Framework Recommended The Following:

- Implementing management and restoration plan to reduce current pressures and maintain future opportunities, e.g. collection and marketing of reeds.
- Enhancing cooperation between key stakeholders responsible for management of Burullus wetland and involving both primary and secondary stakeholders in decision making.
- Clarifying responsibilities between relevant stakeholders and building an interactive data sharing network between them.
- Encouraging private sector for more investments of small and minors industries to increase the local communities' income and best use of its ecosystem services.
- Supporting the touristic potential around the wetland for enhancing the population livelihood.
- Raising awareness of beneficiaries around the wetland that directly affect the wetland ecosystem.
- Enhancing social problems of local communities related to pension, health insurance and sewage services.
- Regular dredging of the wetland area and inlet to ensure the water circulation in the wetland.
- Adequate treatment for agriculture and municipal wastes before being discharged into the wetland.
- Preparing vulnerability zoning map and identifying hotspot areas.

FIGURES

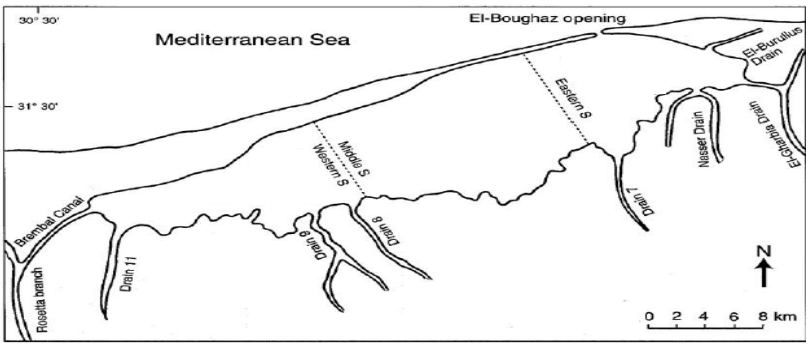


Figure(1): DPSIR framework chain (Smeets & Weterings, 1999)

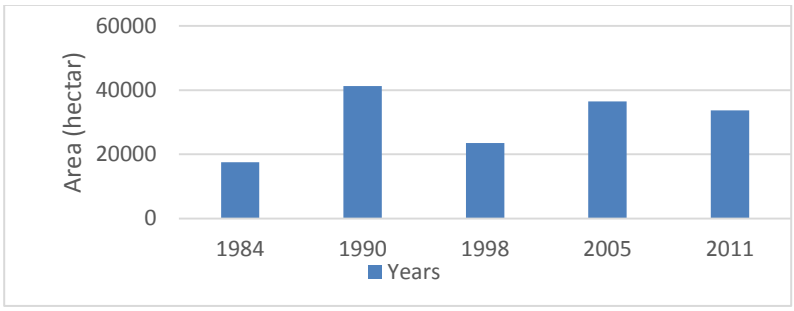


Figure(2): Proposed steps for assessing of Burullus wetland Ecosystem

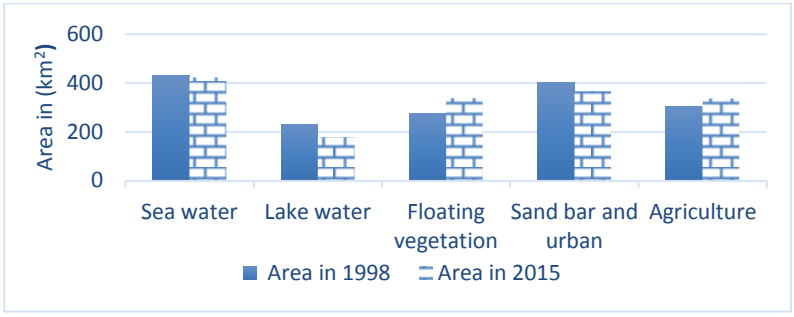
Figure(3): Burullus wetland location in the Nile Delta (Mashaly et al., 2008)



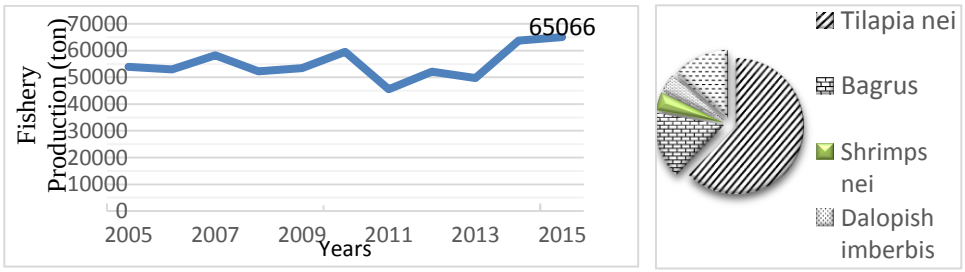
Figure(4): Drains discharged into Burullus wetland (El-Shinnawy I. A., 2003)



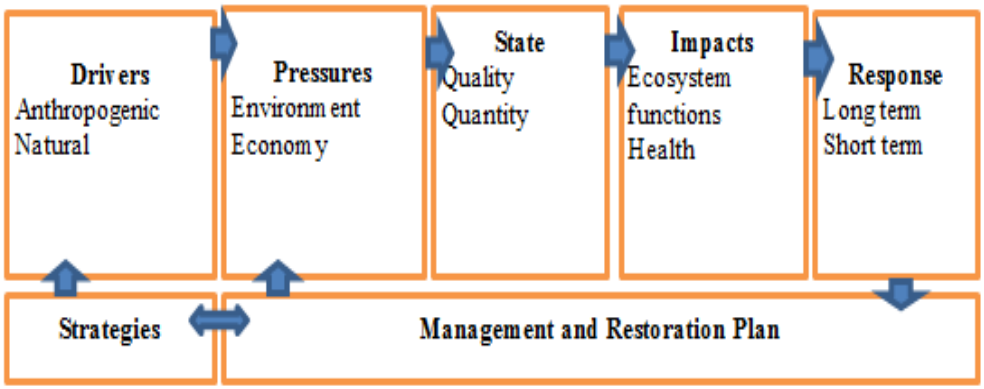
Figure(5): Expansion of fish farms around Burullus wetland (Zingstra, 2013)



Figure(6): Change of LU/LC from 1998 to 2015 (Hossena & Negm, 2016)



Figure(7): Annual trend of fish production (ton) - Percentage of fish type



Figure(8): DPSIR Framework Analysis Chain

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تحليل النظم البيئية لبحيرة البرلس باستخدام إطار عمل DPSIR المحركات – الضغوط – التغيرات – التأثيرات – الإستجابة

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مستخلص

أصبحت الإدارة المستدامة للنظم الايكولوجية للأراضي الرطبة أمراً ضرورياً، وخاصة فى ظل النمو السكاني السريع وزيادة الأنشطة البشرية، بالإضافة إلى تهديدات تغير المناخ. وقد تم تعريف العديد من الأساليب لتحليل وإدارة النظم الإيكولوجية منذ التسعينيات، حيث يمثل اطار عمل المحركات – الضغوط – التغيرات – التأثيرات – الاستجابة DPSIR أحد المناهج واسعة الإنتشار لتقييم وإدراة المشاكل البيئية. وقد طبقت هذه الدراسة إطار عمل DPSIR على بحيرة البرلس كنموذج للأراضي

الرطبة الشمالية المصرية، من أجل تحليل نظامها الإيكولوجي من منظور مدى إمكانياتها لتقديم خدمات النظم الإيكولوجية ضمن الحالة الراهنة للتغيرات الناجمة عن الدوافع الإجتماعية والإقتصادية. حيث أن هذه التغيرات قد تؤثر تأثيراً مباشراً أو غير مباشراً على صحة البحيرة وإنتاجيتها، وبالتالى على وضع السكان المحليين الذين يعتمدون على خدماتها البيئية كمصدر للدخل. تم تحديد خمسة محركات اجتماعية – اقتصادية رئيسية وتحليلهم من خلال إطار DPSIR. تم الاعتماد على تقييم اطار عمل DPSIR فى تحديد بعض التوصيات لعدد من الأنشطة اللازمه لاعادة تأهيل البحيرة فى إطار عمل DPSIR. ويمكن الاسترشاد من نتائج هذه الدراسة في إعداد خطة للإدارة واستعادة النظم البيئية لبحيرة البرلس تطبيقاً لنهج النظام البيئى.

الكلمات الدالة: المحركات – الضغوط – التغيرات – التأثيرات – الاستجابة DPSIR – الخدمات البيئية – بحيرة البرلس – استعادة النظم البيئية