

Master of Landscape Architecture Program (MLA)

Environmental Impact of Constructed Wetland Parks towards achieving Sustainability

Case Study Wetland Park, 10th Ramadan City, Egypt

Research submitted by

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Abstract

The world is confronted with a series of ongoing challenges and crises. Climate change and water scarcity are two challenges facing many countries worldwide. Attempts to address those difficulties using several ways have been thoroughly investigated. Researchers have been concerned about reducing the negative impacts of climate change and natural disasters on urban environments. Embracing nature-based approaches is very crucial and essential for this mitigation to reach positive environmental impacts. This could be achieved through introducing catalyst project that promotes favorable changes and has a positive impact on the environment. Constructed wetland parks, CWP, which consider wastewater as a resource for reuse, are one of the most prominent nature-based projects that aid in overcoming the effects of the two major crises on cities.

There are few tools available for evaluating the success of CWP projects and their multifunctionality, so, it is difficult to determine their performance impacts and their contribution to achieving sustainability. As a result, a recommended set of main influencing impacts is suggested to be convenient in the assessment of CW Parks. These impacts are evaluated for their relevance and function in the CW Park's sustainability through a questionnaire that targets diverse international specialists with varied backgrounds and areas of interest in CW projects. The questionnaire evaluates the relevance weights of proposed various impacts and factors of CW activities and evaluates their importance in achieving landscape sustainability. The analysis of the questionnaire indicated the relevance and convenience of the proposed indicators, as well as their key influence on sustainability. To examine those impacts and to prove the positive contribution of CW Parks in achieving sustainability regardless of the climatic factor, a comparative analysis is conducted for five international case studies across the world with various climatic conditions using the proposed environmental indicators. The study demonstrated the positive contribution of CW Parks on the environment in various climatic conditions. The results of the questionnaire are then utilized to create an assessment tool for evaluating CW Parks' sustainability. With the application of the proposed tool, CWP Index, on a case study in an arid climate in Egypt, the expected performance is evaluated to confirm and answer the Thesis main hypothesis of assessing the positive impacts of CWP in achieving city sustainability.

The proposed CWP index allows practitioners to evaluate the CW Park's overall sustainability performance as well as the sustainability performance during park's phases. This allows for a better understanding of the opportunities for improvements, as well as the planning and design of future CW Parks initiatives. The proposed assessment matrices and visualized charts are seen to be a strong assessment tool, being user-friendly and easy to grasp for all levels of practitioners and serve as a summary of the project's impact assessment reports.

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Declaration of Authorship, Personal declaration:

The author certifies that the material contained in this Master Thesis is the result of personal work and does not contain unacknowledged work of others. Any consultation of published work of others is always clearly attributed to the best of the author's knowledge. Where any quotation from the work of others, the source is always given. With the exception of such quotations the work of this thesis is entirely the author's own work. This Master Thesis has not been submitted for the award of any other degree or diploma in any other institution. The author assumes no liability for the accuracy of information provided despite careful research.

Signature: Aya ElMeligy

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Introduction

Climate change and water scarcity are the two major challenges facing many countries worldwide. Several attempts to face those challenges through different approaches have been deeply studied. One of the prominent projects that helps in overcoming the effect of the two major problems on cities is constructed wetland parks. Wetlands have an important role in the hydrological and chemical cycles, i.e., Water purification and cleansing, retention of nutrients and sediments, flood control and groundwater refill. That is why wetlands are described as “Kidneys of the Landscape”. Also described as “Biological Supermarkets” referring to enriching the biodiversity and the vast vegetations they provide for the environment. (Sandham, L., et al., 2019, EPA, 2021) Sustainable landscapes have been identified during the last decade as a promising area for enhancing sustainable development, which is defined as environmental, economically functional, and socially and culturally beneficial development, so that human and economic benefits can be achieved without jeopardizing nature and resources. (Barmelgy, H., 2013) For the past few decades, more concentration has been given by global researchers on the mitigation of various negative impacts of climate change and natural and human-made disasters in urban areas, particularly considering extraordinary urbanization growth. (Gaber, R., 2020)

Catalyzation is a process in which a new component is added into an environment, where it fosters positive adjustments and adds a constructive effect to the surroundings. (Refaat, D., et al., 2019) Constructed Wetland parks can be used as a catalyst in the urban context of new cities which can contribute a positive transformation and adaptation to the environmental factors and enhancing sustainability and resilience of the city. Nevertheless, they have a great role in promoting healthier social interaction and creating sense of belonging and security to the community. Constructed wetland parks is being used worldwide as an environmental approach for sustainability. It helps achieving several goals like improving biodiversity, habitats, water re-use through water treatment, nevertheless, improving air quality and reducing pollution. This approach has been used in several countries, while in some other countries like Egypt, the technique was only used as small-scale project for water treatment in the northern lake. The mitigation with the technique as a multifunctional park is still being introduced as a project in the new city of 10th of Ramadan. The Multifunctional landscape is the technique of merging the conventional landscape activities with human activities and production. This mitigation creates equilibrium between ecosystems and the human impacts. This is clearly observed in the constructed wetland parks, where the project is a mitigation between landscape ecosystem and the human activities. This approach has been developed in many countries which showed some positive results in the environmental and social fields. (Haron, A. et al., 2020)

Environmental Impact Assessment (EIA) is a method that helps in evaluating and assessing the prospective environmental impact of a project, thus defining its whether positive or negative effect through various measures that affects the environment. This assessment has a crucial role in steering the planning process, where this study is done as a primary stage before the implementation of the project to have the correct decisions and to reduce the environmental impacts and hazards by controlling any expected negative impacts before proceeding with the project’s implementation. These measures cover the most important aspects that have a great role in the climate change and the sustainability of the cities.

This study focusses on developing a conceptual framework of major indicators of sustainable development for the assessment of multifunctional landscapes for CW parks performance. These urban sustainability indicators examine the correlations between environmental, economic and social aspects. With a deep focus on the assessment of the following important environmental aspects, **Climatic Aspects**: covering Air Quality, Urban Micro-Climate and Carbon Footprint. **Sustainability**: covering the Energy, Materials, Solid/Liquid Wastes and Soil Discharges. **Biodiversity**: Flora (Vegetation) & Fauna Habitat Diversity and **Water**: addressing the Water Reused and Water Quality. This EIA system’s main purpose is the preservation and protection of the environment from any risks that could be expected from implementation of new projects to the adjoining environment; land, air, soil, water, biodiversity... etc. (Lexology, 2019) The study measures different environmental performance of flora impacts through the application of i-Tree Eco v6.

Constructed Wetland Parks Benefits

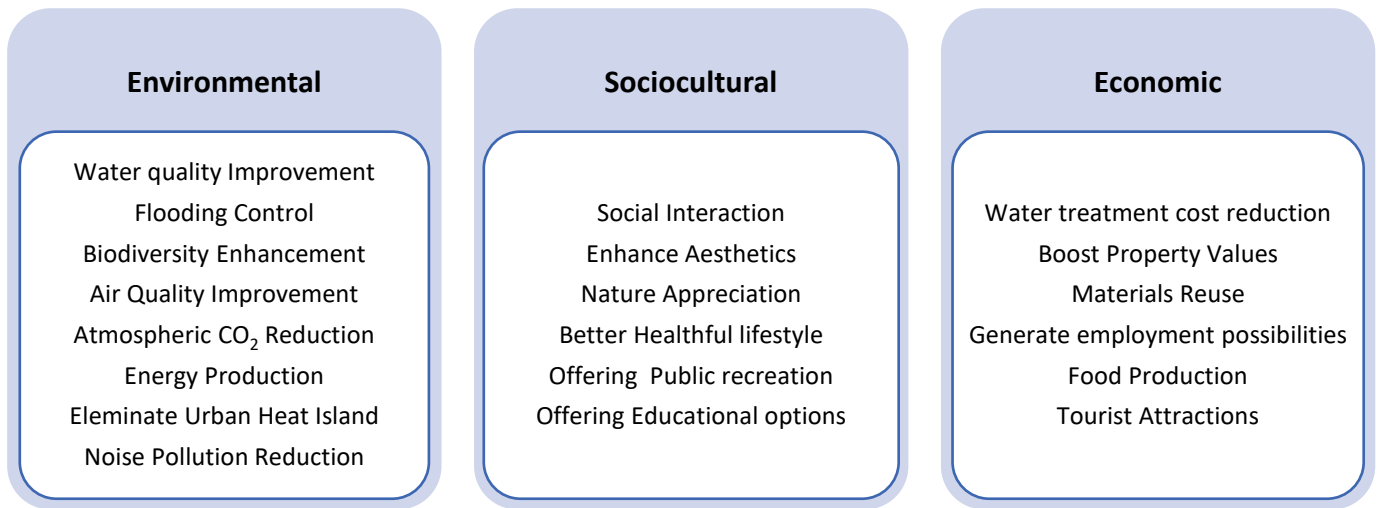


Fig. (1) Constructed Wetland Parks Benefits, Source: Author from Literature review

This thesis calls for the integration of constructed wetland parks in cities to develop a sustainable city that can tolerate the water scarcity, especially in arid climate and adapt to the climate change while introducing more vegetation and biodiversity within the city which in turn enhance the environmental factors with better air quality and reduce the heat island effect and many other environmental aspects in addition to Socio-cultural and Economic-Technical aspects.

Main Hypothesis

This thesis claims the positive environmental, social and economic impacts of constructed wetland parks in achieving sustainability of various climatic cities with a deep focus on an arid climate city.

Research aims

The main objective of the study is the assessment of the positive impact of introducing constructed wetland parks in both old and new cities through a proposed assessment tool that evaluate the impacts of various factors of constructed wetland parks, according to their relative importance weight in achieving sustainability.

Research Questions:

The research will attempt to answer the research questions (RQs):

RQ 1: What is the role of Constructed wetland in the climate change and achieving better environmental measures?

RQ 2: What are the best methods and tools for assessment of sustainable constructed wetland park?

RQ 3: What are the main impacts and factors contributing to the achievement of sustainability in constructed wetland park sites and their relative importance?

Chapter 1: Methodology

1.1. Research Background

This chapter includes the research methodology of the thesis, describing the research approach, the research method, the methods of data collection, the selection of the participants, the research assessment process, and the type of data analysis.

1.2. Research approach

The research starts with the study of major literature review for the understanding of the important factors affecting the major pillars of sustainability, the validation of various assessment tools. After a thorough understanding of the factors and after the validation of major assessment tools, the research proposed a set of major influencing impacts that are most convenient in the assessment of CW Parks. These impacts are then evaluated for their importance and role in the sustainability of the CW Park through a questionnaire to reach an average relative weight for each impact reflecting their convenience in the evaluation process and their importance role in the sustainability of the CW Parks. At this point, analysis of performance of various case studies is performed for the objective of assessing the positive contribution of CWP in achieving sustainability in diverse locations around the world and in various climates, to prove the positive contribution of CWP in achieving sustainability regardless of the climatic factor. The research then develops the assessment tool according to the questionnaire results to reach a well-structured, easy to use assessment tool for evaluating CW Parks' sustainability and highlights on a case study of CWP in arid climate in Egypt, where the expected performance is assessed through the proposed CWP Index for the confirmation and answering of the Thesis main hypothesis of the effective assessment tools for assessing the positive impacts of CWP in achieving sustainability of cities.

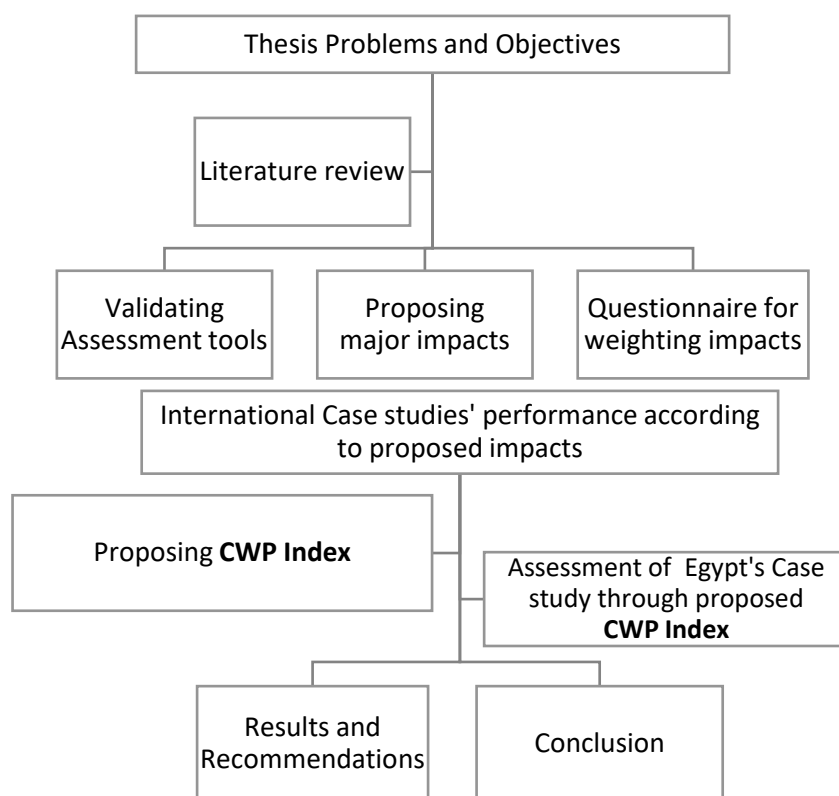


Fig. (2) Thesis Approach, Source: Author

1.3. Research Methodology

For the fulfillment of the thesis objectives, the study consists of three main parts based on the following methodologies:

1.3.1. Observation:

The first part is a theoretical investigation based on the various definitions and main principles of constructed wetland parks in cities and the recent environmental impact assessment factors that defines its positive intervention on cities.

1.3.2. Quantitative Framework Index:

In the second part, the research will study various assessment tools for the understanding of impacts of various environmental factors in the purpose to achieve sustainability in vulnerable cities of diverse climates internationally, depending on a multi-criteria framework addressing various environmental causes of risk. The proposed assessment will consider man-made causes as well as natural hazards to contribute to achieving resilience in cities around the world. For the quantitative analysis, a questionnaire was used, structured and conducted to measure the weights of the identified impacts and measure's reliability of these impacts on the CWP sustainability.

For a precise and accurate assessment of park performance, a specific designed constructed wetland parks' index is proposed which can fit various parks in relation to their different types, circumstances and characteristics. Using the Evaluating Landscape Performance guidebook for Metrics and Methods Selection, which is produced by Landscape Architecture Foundation in 2018, different matrices were selected to be used for the measurement of performance of the impacts according to each park's characteristics.

1.3.3. Possible Sources of Data and Information

The data used for the analysis of both primary and forecasting measures were a mix of different possible sources. (LAF, 2018)

Background Information

- Project design documents, reports, and photos
- Environmental Impact Assessments
- Historic preservation or cultural documentation

Predictive Models and Calculators

- Project studies related to wildlife, transportation, noise, etc.
- Rating system submittals (LEED, SITES, etc.)
- Online calculators and tools

Secondary Data

- Public agency datasets, records, or publications
- Private entity records or publications
- Utility and other service providers
- Citizen science data

Primary Data

- On-site measurements or monitoring
- Direct observation
- User surveys or interviews

1.3.4. Questionnaires:

The questionnaire was designed to target participants of professional background on constructed wetlands from different countries to allow for an indicative global assessment. The participants were invited for participation through online platforms; emails, WhatsApp and Facebook.

1.3.5. Analytical review

The next part is an analytical review of case studies of different successful constructed wetland parks worldwide, aiming to assess these various and diverse initiatives, and to examine the aims, approaches and action plans adopted to achieve resilience and enhance the environmental aspects. Both qualitative and quantitative research methodologies were used to analyze multiple case studies.

1.3.6. Quantitative Analysis:

Finally, the research will propose a detailed environmental impact assessment of a set of important environmental factors to achieve resilience in vulnerable, arid new city in Egypt depending on the proposed multi-criteria framework of various sustainability causes of risk. The proposed assessment contributes to achieving resilience in new cities and applying it to selected new city in Egypt.

1.4. Research Structure

| | |
|--|--|
| Chapter 1 Background & Methodology | <ul style="list-style-type: none">• Research Background and Methodology |
| Chapter 2 CWP Approaches & Benefits | <ul style="list-style-type: none">• Literature Review• Definitions of Wetlands / Constructed wetland / CW parks• Benefits and role of wetland parks for ecology / Biodiversity• Environmental Impact Assessment, EIA |
| Chapter 3 Environmental Assessment Indicators for CWP | <ul style="list-style-type: none">• Environmental; <i>Climatic, Sustainability, Biodiversity, Water</i>• Social and cultural; <i>Community, Social, Aesthetic</i>• Economy and Technology; <i>Economic, Technical values</i> |
| Chapter 4 CWP International Case Studies comparative analysis | <ul style="list-style-type: none">• Comparative Study• Case studies of top constructed wetland parks approaches• Criteria: Park, Arid, 10 years, Scale• <i>Riyad, Tangshan, Tianjin, Shanghai, Los Angeles</i>• Comparative analysis and achievement based on Indicators |
| Chapter 5 Assessment Tool | <ul style="list-style-type: none">• CWP Assessment Index Framework• <i>Proposing CWP Index for Assessment</i> |
| Chapter 6 Case Study, Egypt | <ul style="list-style-type: none">• "Case study: Wetland Park Egypt"• Park's performance analysis and its influence on sustainability• Park's Impact assessment according to proposed CWP Index |
| Chapter 7 Conclusion | <ul style="list-style-type: none">• Findings and Results• Limitations and Recommendations• Conclusion |

Fig. (3) Thesis Structure, Source: Author

Chapter 2: Literature Review

Introduction

This chapter provides a review of significant literature related to constructed wetland parks and their environmental evaluation, as well as a comprehensive discussion review of prior research done globally to achieve a clear grasp of the environmental advantages and strategies of constructed wetland parks.

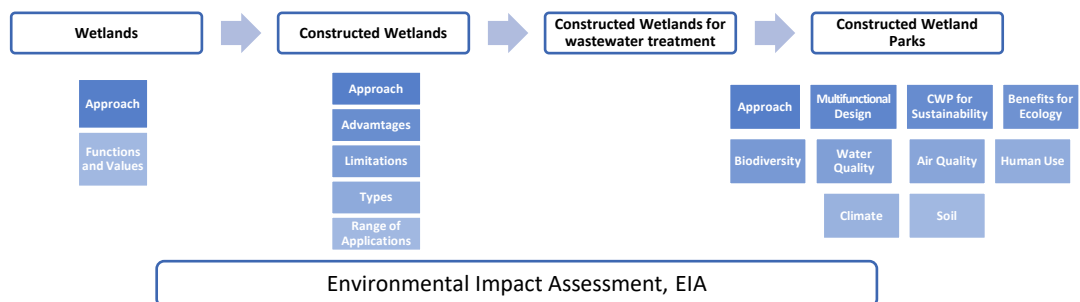


Fig. (4) Chapter 2, Methodology and structure, Source: Author

Rapid urbanization and population growth are causing chronic problems and stress for cities around the world, including increased levels of air, water and noise pollution, increased exposure to urban heat islands, resource scarcity and environmental degradation, moreover, developing countries such as Egypt and many other countries around the world are facing water scarcity. Hence, Water is considered a cherished resource due to overpopulation, so great efforts are being made for the efficient and optimum use of water for the benefit of future generations. (Haron, A. et al., 2020)

2.1. Wetlands

The term "wetlands" includes a wide range of wet ecosystems which are intermediate areas between water and land; this includes swamps, bogs, marshes, floodplains, tidal wetlands, wet meadows, and ribbon (river) wetlands along flow channels. Hence, the border between wetlands and tableland or deep water is not always definite. (Davis, L., 1995) It is described as a unique and distinct ecosystem, which is permanently or seasonally flooded, predominating oxygen-free processes, with the advent of adaptive aquatic vegetation, distinctive to unique aquatic soils, which is the main distinguishing feature from other terrain or bodies of water (Omondi, D. et al., 2020)

2.1.1. Wetlands – approach

Wetland hydrology flow is generally slow, with shallow water or saturated substrates. Slow currents and shallow water can cause sediment to settle as water flows through wetlands. The slow currents also ensure long contact times between the water and the wetland surfaces. The organic and inorganic substances' complex mass and the distinct possibilities of gas and water exchange promote a vast number of microorganisms that decompose or transform a variety of substances. (Davis, L., 1995) Water has always been purified as it flows through wetlands, lakes, rivers, lakes and streams through natural processes. In the past few decades, constructed systems have been developed to improve water quality using some of these processes. (Omondi, D. et al., 2020) (Davis, L., 1995)

2.1.2. Wetland functions and values

Wetlands offer several functions and values; presented in the occurring inherent processes; and the society perceived valuable traits, respectively. (Omondi, D. et al., 2020) (McCartney M., et al., 2015) Not all wetlands necessarily offer all the functions and values, but usually provide many benefits. Under proper conditions, CWs can provide: (Omondi, D. et al., 2020; Davis, L., 1995)

- Improvement of water quality.
- Flood storage and desynchronizing of storm
- Nutrients and other materials cycling benefits
- Biodiversity; Fish habitat and wildlife
- Passive recreation enhancement, for example photography and bird watching
- Active recreation, for example hunting, education and research
- Enhance aesthetics and landscape merit.

2.2. Constructed Wetlands

Constructed wetlands (CWs) are man-made engineered systems for water treatment mainly designed and constructed to mimic the function of natural wetlands with a major objective of water purification by utilizing the natural role of aquatic vegetation, soils and their microbial inhabitants, solar energy and gravity to remove contaminants in surface water, groundwater or wastewater streams by chemical, physical, and biological treatment processes to improve the quality of the provided incoming flow (Gaber, R., 2020; Haron, A. et al., 2020; Hoffmann, H., 2011; Mohamed, H. et al., 2014)

CWs is an artificial ecosystem that was originally developed to utilize and restore the biodegradability of vegetation, about forty years ago in North America and Europe, with low construction and operating costs advantages in addition to the possibility of using it alone or in combination with other systems. (Haron, A. et al., 2020) CW systems are particularly appropriate in developing countries for small communities due to the significant potential health benefits from pathogen removal (Yang, W. et al., 2008). Due to its low cost and energy savings in addition to its advantages of versatile reuse of high-quality wastewater, self-treatment and self-adaptation to surrounding conditions and the environment, hence, it has proven to be an attractive and stable alternative. (Zhang, D. et al., 2009). Regulating greenhouse gases, minimizing heat island effect, habitats of distinct species, recreational services, social and economic benefits, scientific and educational values are some of its functions and added values for human well-being. (Haron, A. et al., 2020)

2.2.1. Constructed wetlands – approach

CWs occupy a relatively larger area of land and have lower energy consumption and lower labor costs. They are an attractive alternative for communities since they are sustainable, extremely cost effective by successfully reusing wastewater as purified water and a source of nutrients in the form of plant nutrients instead of waste or pollution. That's why CWs have numerous advantages over traditional technical systems: high performance, less energy, sequester carbon, less operation and maintenance, more capable of dealing with the effects of climate change and a significant role in many *ecological sanitation* (ecosan) concepts. (Albold A. et al., 2011; Hoffmann, H., 2011) Mainly used to remove pollutants and produce adequate quality wastewater for reuse or release into the environment, through the treatment of municipal, industrial and agricultural wastewater and rainwater (Mohamed, H. et al., 2014). It eliminates the following pollutants:

- Suspended matter
- Soluble organic matter
- Phosphorus and Nitrogen
- Metals
- Pathogens

CWs can perform distinctly than natural wetlands and can perform many of the traditional wastewater treatment systems' functions if well-designed, managed, operated and maintained. (Mohamed, H. et al., 2014) A common characteristic of all types of wetlands, natural/constructed, fresh/salty, is the presence, at least occasionally, of surface or near-surface water. Hydrological conditions, in most wetlands, cause the substrate to saturate long enough during the growing season to create hypoxic conditions in the substrate. This lack of oxygen in the substrate reduces it and limits vegetation to species that are adapted to low-oxygen environments. (Davis, L., 1995)

CWs' technology is considered a viable, easy-to-operate, and low-cost alternative to traditional wastewater treatment systems. (Haron, A. et al., 2020) Their uniqueness is due to the use of natural flora, microorganisms and soil as basic components in the treatment process. (Ezeah, C. et al., 2015) It is now widely used in many countries as an ecological tool to achieve multiple benefits, such as increasing biodiversity and habitat, treating water and reducing air pollution. In the past decade, this technology has been used in Egypt as a water treatment tool for small projects in the northern lakes. They are now commonly used as an ecological tool in many countries. It brings many benefits, such as increasing biodiversity and habitat, treating water, and reducing air pollution. In the last decade, this technology has been used in Egypt as a water treatment tool for small-scale projects in the Northern lakes. (Haron, A. et al., 2020)

The technology of using plants in the treatment of polluted wastewater is an attractive method that can be exploited in drains, as these weeds can purify water quickly and effectively through the presence of water weeds in the drain path, with a length ranging from 500 meters to 1000 meters, this purified water can be reused in agriculture or industry. (AbouElElla, S., 2017)

The use of aquatic plants to purify water in drains is the same idea applied to plant treatment plants (artificial wetlands), which are basins planted with plants, and these basins are defined as semi-saturated water areas, which are engineering designs (artificial) that can initially remove pollutants from watercourses and thus improve the specifications of the final treated wastewater before being discharged or reused. (AbouElElla, S., 2017)

2.2.2. Advantages of constructed wetlands

Constructed wetland has several advantages which makes it a cost-effective and technically feasible method for wastewater and runoff treatment: (Omondi, D. et al., 2018) (Davis, L., 1995)

- **Cheaper construction** than other treatment options with low operating and maintenance costs
- **Periodic on-site labor** is required for operation and maintenance.
- **Flow instability tolerance** facilitating the reuse and recycle of water.

In addition:

- **Provides habitat for numerous wetland organisms**, fitting harmoniously into the landscape
- **Wildlife habitat and aesthetic enhancement** beside improving water quality and various benefits
- **Well-accepted Environmentally Sensitive approach** by stakeholders and communities.

2.2.3. Limitations of Constructed Wetlands CW

There are limitations associated with the use of constructed wetlands: (Omondi, D. et al., 2020; Davis, L., 1995)

- Requires more land area than traditional wastewater treatment systems.
- Although wetland treatment may be economical compared to other options, this only applies to places where land is available and affordable.
- Less consistent performance efficiency compared to the traditional treatment.
- The treatment efficiency may vary; **seasonal variation** due to changing environmental conditions, such as precipitation and drought, or **spatial variation** due to weather conditions in different locations.
- While average year-round performance efficiency may be acceptable, fluctuations lead to unreliability if the wastewater quality must meet constant strict discharge standards.
- Biological components sensitivity to toxic chemicals, such as ammonia, and other pesticides that are regularly washed or discharged by the water flow, causing a temporary reduction in treatment effectiveness and efficiency.
- CWs require a minimal amount of water for adequate survival and improved efficiency, i.e., intolerance to complete drought, unlike wetlands which can tolerate temporary degradation, also some plants do not tolerate complete submergence.
- CWs for wastewater treatment and flood control are relatively new concepts, yet no consensus has been reached on the optimal design and the information available about their long-term performance is insufficient. In addition, no full recognition about its ability and potential in eliminating emerging contaminants such as resistance genes.

2.2.4. Types of constructed wetlands

Constructed wetlands include several types; Surface-Flow wetlands, Subsurface-Flow wetlands, and hybrid systems which combine surface and subsurface flow wetlands to utilize the specific advantages of both systems. (Omondi, D., 2017; Vymazal J., 2005) (Omondi, D. et al., 2020; Davis, L., 1995; Hoffmann, H., 2011) CWs can be classified according to their operation mode as surface-flow, horizontal-flow, vertical-downflow or up-flow, through microbial activity, nitrogen and phosphorus removal via denitrification, plant uptake and sorption, a reduction in BOD and solids takes place. (Blumberg, 2019) For higher treatment efficiency, CW systems can also be combined with traditional treatment technologies. (Van-Biervliet O., et al., 2020) Based on the current environmental conditions and their suitability for domestic wastewater, agricultural wastewater, coal mine drainage, and storm water, the types of constructed wetlands are selected. (Omondi, D., 2017; Davis, L., 1995)

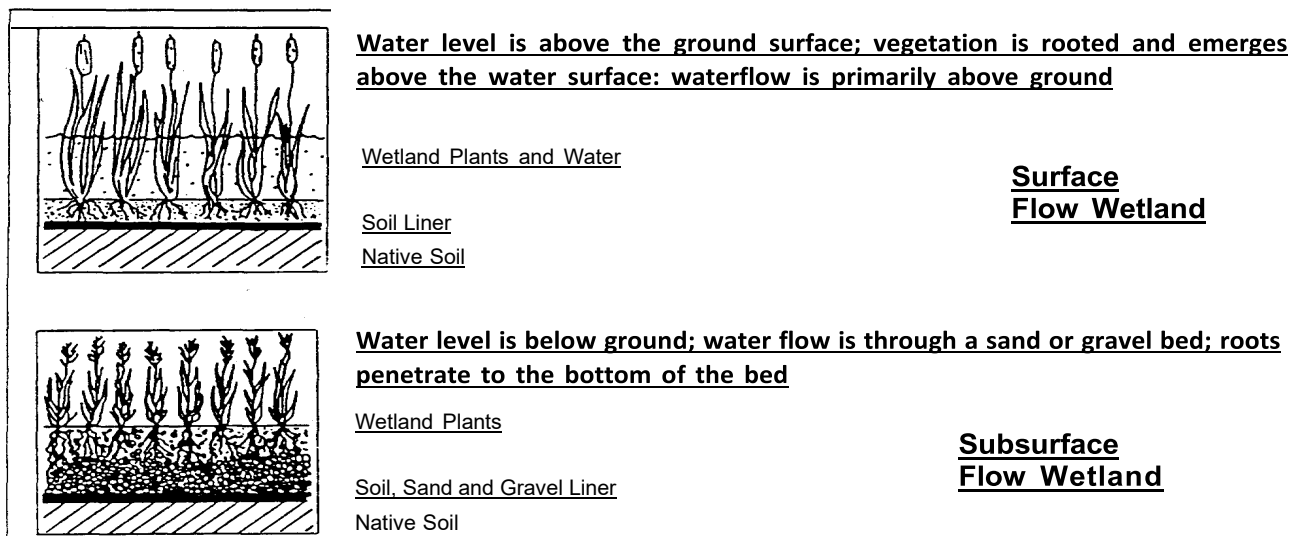


Fig. (5) Surface and subsurface flow constructed wetlands (from Water Pollution Control Federation 1990).
Source: (Davis, L., 1995)

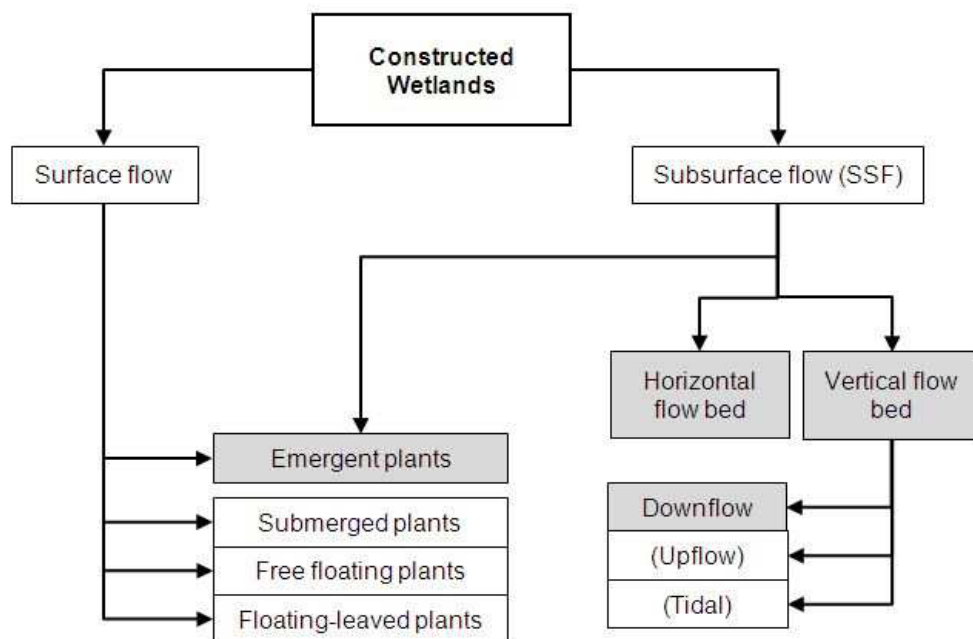


Fig. (6) Constructed wetlands Classification (modified from Vymazal and Kroepfelová, 2008).

"Emergent plants" are a type of macrophyte where the leaves are above the water level.

"Macrophyte" are aquatic plants that normally grow in or near water

Source: (Hoffmann, H., 2011)

2.2.5. Range of applications

Constructed wetlands' applications has various range of use: (Hoffmann, H., 2011)

1. Municipal wastewater treatment
2. Treatment of domestic sewage or gray water
3. Tertiary treatment of wastewater from conventional sewage treatment plants
4. Treatment of industrial wastewater, i.e., landfill leachate, waste from petroleum refineries, drainage of acid-mine, agricultural waste, wastewater from pulp and paper mills, textile mills.
5. Dewatering of Sludge and mineralization of faecal-sludge or sedimentation tanks sludge.
6. Rainwater treatment and interim storage.
7. Swimming pool water treatment without chlorine

2.3. Constructed wetlands for wastewater treatment

In 1952, the German scientist Dr. Seidel at the Max Planck Institute in Germany made the first attempts on the possibility of treating wastewater with wetland plants. (Seidel, 1965) The number of CWs rose sharply in the 1990s when the experiments developed to treat different types of effluents such as industrial wastewater and rainwater. (Hoffmann, H., 2011) Gradually, the use of constructed wetlands for wastewater treatment has spread and is becoming increasingly known and popular in many locations around the world, where subsurface flow CWs are wide spreading in many developed countries such as Germany, Great Britain, France, Denmark, Austria, Poland, Italy and are also suitable for developing countries, however more knowledge and publicity should be promoted about it. (Mohamed, A., 2004; Heers, M., 2006; Kamau, C., 2009; Hoffmann, H., 2011)

A constructed wetland for wastewater purification and detoxification is a simple concept intended to simulate natural wetlands processes such as filtration, sedimentation, microbial interaction, chemical precipitation, and plant uptake to absorb soil particles, enhancing the ability of wetlands to eliminate many nutrients, including carbon, nitrogen, sulfur, potassium and phosphorous, increasing water quality (Haron, A. et al., 2020; Kadlec, R., et al., 1996) This could be achieved through alteration of water depth, oxygen content, flow rates, and growing vegetation within the systems, increasing the biological productivity, rates of degradation and removal. (EPA, 2000) Classifications of constructed wetlands for wastewater treatment can be according to the life-form of dominant macrophyte, such as free-floating systems, leaf-floating, emerging rooted, and submerged macrophytes, and can also be classified according to wetland hydrology and subsurface flow (Vymazal J., 2010).

Lifetime: CWs for wastewater treatment may have a specific lifespan defined by wastewater loading, the wetland's ability to remove and store pollutants, and litter accumulation. Many systems have been in operation for over 20 years and have suffered minor, or none, loss of efficiency. With more monitoring of CW systems over longer periods of time, long-term data their performance will be obtained. So far, provided long-term data from some CW systems have shown that provided that loads are appropriate, and the wetland system is carefully designed, constructed and maintained treatment performance for wetland soluble pollutants such as BOD₅, TSS (total suspended solids) and nitrogen is not reduced. Accumulation of retained pollutants in wetlands, such as phosphorus and metals, should be observed regularly to evaluate wetland performance as the wetland's pollutants removal and storage capacity can be reduced over time. Wetland deposits and waste could be extracted periodically, if required, and reconstruct the wetland with a new substrate, as wetland can expand to accommodate sediment deposits, with the assumption that the accumulation of pollutants in sediments and wastes represents a long-term basin of pollutants. (Davis, L., 1995)

2.4. Constructed Wetland Parks, CWP:

CW Park is a nature-based multifunctional landscape project that manage various ecosystem functions and supports the transformation of the project site into a living system that provides a comprehensive environmental service including water treatment, biodiversity, urban agriculture and flooding combined with community engagement through an educational and aesthetic form. (Haron, A. et al., 2020)

2.4.1. CWPs – approach:

The concept of a sustainably constructed wetland park incorporates landscape and ecological features and functions, and thus minimizing and limiting water and air pollution levels, enhancing food security and livelihoods, protection of various species and ecological functions as well as meeting cultural, aesthetic and recreational needs. (Haron, A. et al., 2020)

2.4.2. Multifunctional design

Constructed Wetland's design includes various goals and objectives, some of which can be achieved simultaneously, these includes: (Bendoricchio, G., et al., 2000)

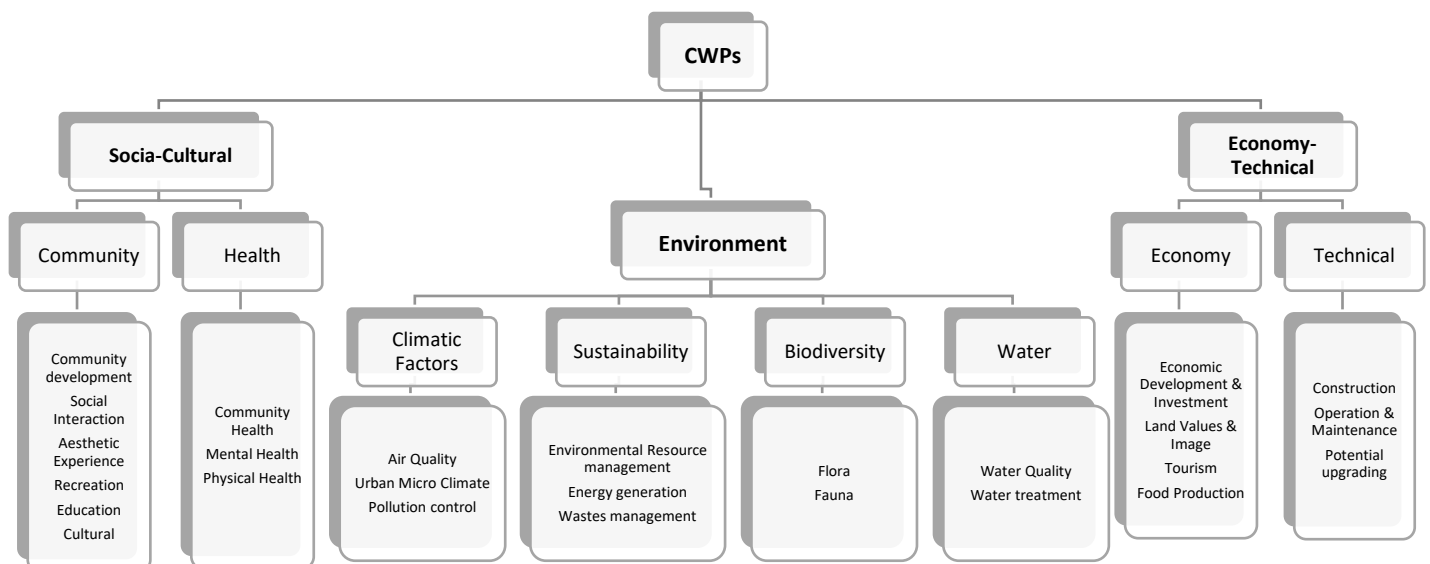
- Improvement of the water quality through the absorption and removal of sediments, nutrients and other pollutants
- Water storage and flood protection
- Groundwater recharge
- Support in the initial production and in the design of food webs,
 - Photosynthesis,
 - Wildlife
 - Food web and habitat diversity
 - Neighboring ecosystems export
- Use by humans
 - aesthetic applications
 - recreational
 - commercial
 - educational

A multifunctional landscape encompasses conventional uses of the landscape, human activities and production, and this complex coherence balances ecosystems with human impacts. The new approach of establishing a CW park as a multifunctional tool for landscaping has many successful stories in many countries worldwide. (Haron, A. et al., 2020)

2.4.3. Constructed wetland parks for sustainability

CW are increasingly recognized as low-cost and energy efficient natural ways of treating variable wastewater while providing the potential to achieve several benefits, such as a CW Park that offers the possibility for integrating the CW into parks and recreational activities enhancing wildlife habitats, aesthetic values and high quality wastewater that can be recycled for landscape irrigation or sequestered in an attractive and educational pond that is valuable in attracting wildlife while providing information on wetland practices. (Haron, A. et al., 2020) All these benefits could place constructed wetland gardens in the sustainable landscape category, primarily because of their ability to provide multiple functions and benefits at low cost and low ecological impact (Wu, H., et al., 2015). CW parks can offer various environmental, ecological, socio-cultural and economic benefits which are the main pillars in achieving sustainability of cities. (Haron, A. et al., 2020)

Fig. (7) Constructed wetland Park for sustainable communities, Source: Author, modified from (Haron, A. et al., 2020)



2.4.4. Benefits of Constructed Wetland Parks, CWPs:

Constructed wetland parks can offer various environmental, economic and sociocultural benefits. In addition to the biological water treatment system, the parks include vegetation, biodiversity enhancement, prospects for economic benefits and social activities and healthy lifestyles opportunities for the community, and hence providing diverse benefits to both the environment and the social life.

Biological Treatment importance:

Biological treatment is the process of selecting a living organism that can rid us of some pollutants in the environment around us (water - air - soil). When choosing a living organism: a plant - an animal - a microorganism (bacteria) to remove some environmental pollutants, the expected output of these pollutants is: (Aamer, W., 2011)

- 1- The treated pollutant is completely unaffected
- 2- Producing new compounds that are easy to decompose environmentally
- 3- Production of inert compounds that are not harmful to the environment.
- 4- Producing less dangerous compounds than the original compound, so the products must be well evaluated so as not to be more dangerous.

Therefore, we can summarize the importance of the biological treatment process in: (Aamer, W., 2011)

- 1- Converting inactive compounds into active compounds.
- 2- Removing materials that take a long time to decompose, such as plastic.
- 3- Converting pollutants into safe or at least inactive compounds.
- 4- Preserving human life.
- 5- Conservation of environmental resources.
- 6- Treating pollutants that cannot be chemically treated, such as asphalt.
- 7- Reducing the use of chemicals in the treatment of pollutants.
- 8- Saving the life of animals and aquatic plants.
- 9- Cleaning the soil from pollutants and reusing it.
- 10- Preserving the water resources and reusing the treated ones.

2.5. CW Parks' benefits for Ecology and Ecosystem:

Currently, four out of five Europeans live in urban areas and their quality of life directly depends on the state of the urban environment. Cities are highly artificial and man-made places where air quality is extremely variable. Although the alteration of the level of light and noise are also forms of urban pollution, the main pollutants of the air are chemical pollutants, due to the impact they have on human health, ozone (O_3), sulfur dioxide or sulfur dioxide (SO_2), nitrogen oxides (NO_x), fine dust (PM_{10}), carbon monoxide (CO) and carbon dioxide (CO_2). (Qualivivia Project, A8, G3, 2011)

Urban plants can have a significant impact on the quality of the environment and urban life. In addition to the well-known aesthetic and recreational functions, it has been scientifically proven that urban green spaces contribute to mitigating the pollution of various environmental matrices (air, water and soil) improving the microclimate of cities and contribute to the preservation of biological diversity and providing useful information for planning and managing urban green spaces and maximizing the potential benefits of health and hygiene in urban communities. (Qualivivia Project, A8, G3, 2011)

Benefits related to pollution mitigation:

- Improvement of climatic extremes and mitigation of heat islands
- Carbon storage and sequestration
- Reduction of noise pollution
- Improvement of air quality
- Improvement of water quality
- Reduction of the temperature of parked cars
- Reduction of electricity consumption for heating and cooling

Other benefits

- Aesthetic contribution and visual amenity
- Architectural enhancement of buildings
- Increase in property value
- Increased privacy, barriers against unpleasant or stressful views
- Urban reverb control
- Improvement of livability and quality of life in the city
- Increase in tourism
- Increased opportunities for recreational activities outdoor
- Contribution to human health, reduction of stress and anxiety level
- Attraction for birdlife and other wildlife

There are numerous benefits for greenery and vegetation of the CW parks in the contribution to pollution reduction and ecology enhancement, the main important benefits could be discussed in the following points: (Taha, T., 2009)

2.5.1. Modification of air components:

Trees and green spaces are considered the lungs of the city, releasing massive amounts of oxygen during the day that contribute to the modification of the components of the air for the benefit of humans, where one kilometer of trees can release between one to three tons of oxygen per day. (Taha, T., 2009) Green leaves absorb carbon dioxide and use it in the processes of photosynthesis and the release of oxygen to replace what is consumed by living organisms, cars and various combustion processes. Studies say that a single tree can absorb what is emitted by a car that travels 2,500 km per year, where for estimating the city's needs for the purpose of adjusting the air components, some experts go to calculate the number of cars in the city's streets - then estimate the necessary afforestation according to the equation: The total needs of trees in the city and its outskirts = Number of cars on city streets x 3, 4 or 5. (Taha, T., 2009)

2.5.1.1. Estimation of the CO₂ Seizure, Modification of air components:

Trees sequester atmospheric CO₂ and fix it in their tissue at a variable rate based on parameters such as maturity size, longevity and growth rate (Nowak, D., et al. 2002). Larger trees have more leaf surface to trap pollutants and tend to remove more CO₂ from the atmosphere (Wee, M., 1999). Calculations by (Akbari, H., 2002) showed an average CO₂ removal of about 4.6 kg per year over the life of a tree up to a crown width of 50 m². As the tree grows, the rate of carbon sequestration increases to 11 kg per year (more than 50 m² of foliage). However, (Gerhold, H., 2001) calculated that the amount of carbon stored in city trees excluding leaves and roots, varies from 2.1 kg for young trees up to 37.5 kg for large trees. As for (Rosenfeld et al., 1998), the same trees would also avoid the burning of another 18 kg of carbon per tree and year, thanks to indirect action on the heating/cooling of buildings. In fact, several studies have shown a net reduction in energy use and a relative reduction in CO₂ emissions from trees planted near buildings, with seasonal energy savings of 30 to 50%. (Akbari, H., 2002; McPherson et al., 1994; Qualivivia Project, A8, G3, 2011)

Annual absorbed CO₂ by the trees in CW Park (in kg), could be calculated using the following formula (adapted from Nicese & Lazzerini 2013): (Di-Cara, F., et al., 2020)

$$\text{CO}_2 \text{ (kg/year/plant)} = \text{total dry weight} \times 0.5 \times 3.667 \quad \text{Equation (A)}$$

where **0.5** represents carbon content of the dry weight of the plant

3.667 conversion of the carbon value into carbon dioxide

Dry weight of stems, branches and roots, could be calculated using allometric formulas based on the diameter of the plant at a height of 1.30 m, (**DBH**) (Nicese & Lazzerini 2013): (Di-Cara, F., et al., 2020)

$$\text{(T) trunk } \log_{10}(y) = 2.32 \log_{10}(x) - 0.95$$

$$\text{(B) branches } \log_{10}(y) = 2.35 \log_{10}(x) - 1.84$$

$$\text{(R) roots } \log_{10}(y) = 1.98 \log_{10}(x) - 1.10$$

where **y** represents the dry weight in **kg**

x **DBH** diameter at breast height (1.30 m) in **cm**

DBH *Circumference / 3.14 (π)*

$$\text{(TDW) Total dry weight / plant} = \text{T} + \text{B} + \text{R} \quad \text{Equation (B)}$$

$$\text{CO}_2 \text{ sequestered /year /plant (in Kg)} = \text{TDW} / \text{age of plant} \quad \text{Equation (C)}$$

$$\text{CO}_2 \text{ seq. /year /plant species} = \text{CO}_2 \text{ seq. per plant} \times \text{No. of plants} \quad \text{Equation (D)}$$

$$\text{Total Park's CO}_2 \text{ seq. /year} = \text{Sum of CO}_2 \text{ seq./year/plants for all species} \quad \text{Equation (E)}$$

To estimate the probable value of CO₂ sequestration the next steps could be used: (Di-Cara, F., et al., 2020)

In the case of **urban trees**, indicative average values of CO₂ absorption range between 12.46 - 21.60 kg CO₂/year/plant (Municipality of Carimate, 2017; Zirkle et al. 2012), with an average of (17.03 kg CO₂/year/plant).

$$\text{Theoretical Park's CO}_2 \text{ seq. /year} = 17.03 \times \text{No. of plants in Park} \quad \text{Equation (F)}$$

$$\text{Average Park's CO}_2 \text{ seq. /year} = \frac{\text{Equation E} + \text{Equation F}}{2} \quad \text{Equation (G)}$$

In the case of **shrubs**, the indicative average values of the CO₂ sequestration range between 0.27 - 0.84 kg/year/cad, with an average of 0.56 kg/year/cad,

$$\text{Theoretical shrub CO}_2 \text{ seq. /year} = 0.56 \times \text{No. of shrubs in Park} \quad \text{Equation (H)}$$

To obtain a unitary reference value (for the full field)

$$\text{Unit reference Value} = \frac{\text{CO}_2 \text{ seizure value}}{\text{Park's surface area.}} \quad \text{Equation (I)}$$

To estimate the amount of oxygen released by the plants, the photosynthesis formula shows that for each mole of CO₂ absorbed, a mole of O₂ is emitted. The quantity of O₂ emitted into the atmosphere, could be obtained from the calculated kg of CO₂ using the molar masses (Nowak, D., et al. 2007; Di-Cara, F., et al., 2020)

$$\text{O}_2 \text{ (kg/year)} = \text{CO}_2 \text{ sequestered (kg/year)} \times (\text{MMO}_2/\text{MMCO}_2) \quad \text{Equation (J)}$$

Where $\text{MM O}_2 = 31.998 \text{ g/mol}$
 $\text{MM CO}_2 = 44.009 \text{ g/mol}.$

To estimate the number of people supplied by the annual park's produced oxygen, the following equation could be used, considering that one person consumes about 0.80 kg of O_2 /day:

$$\text{No. of people supplied by O}_2 = \text{Park's annual emitted O}_2 / 0.80 \quad \text{Equation (K)}$$

2.5.1.2. Compensation of CO_2 Emitted into the Atmosphere

Vegetation represents a unique simplest and most efficient option to reduce carbon dioxide emissions and contain climate change, where plantation of trees around industrial constructions and along communication roads guarantees a constant permanent uptake of polluting particles and enhance the activities towards the sustainability standards. Vegetations provide healthy and pleasant workplaces, while improving the productivity and welfare of work personnel, where the vast presence and proper management of plants leads uniquely to positive environmental and economic impacts. (Di-Cara, F., et al., 2020)

The average annual amount of CO_2 uptake by a tree in good condition is required in order to calculate the required number of trees to offset CO_2 equivalent emissions. In urban areas the concentration of CO_2 in the air is much higher than in rural areas, and therefore plants photosynthesize at much higher speeds, resulting in more annual sequestration of CO_2 . (Di-Cara, F., et al., 2020) Average absorption data available from various bibliographic sources (for example GAIA Project, 2015, IBIMETCNr, 2015; AVI, 2021) are specific to individual tree species most used and suitable for the urban environment. The generic CO_2 absorption average value mentioned in various literature was equal to 86 kg CO_2 /tree/year. (Di-Cara, F., et al., 2020)

To estimate the number of trees capable of offsetting these emissions, for each are square meter:

$$\text{No. of trees required/ area m}^2 = \frac{\text{Total CO}_2 \text{ emissions}}{\text{average annual CO}_2 \text{ seized / tree}} \quad \text{Equation (L)}$$

Species with higher CO_2 sequestration rates require fewer trees, and these most performing species have an average net absorption value of 144 kg / tree / year. While other species are less efficient in CO_2 sequestration (GAIA Project, 2015; Qualivivia Project, A8, G3, 2011; IBIMETCNr, 2015). This certainly does not mean avoiding the use of these types in urban areas, as many of them are of great decorative value or are particularly adaptable, but instead should be properly combined with other more performing types; If the main objective is to reduce the concentration of CO_2 in the air. Moreover, the climatic characteristics related to the planting site are important: a plant that is potentially less efficient at sequestering CO_2 can give much better results than another that is more performing but not suitable for the specific planting location. (Di-Cara, F., et al., 2020)

Tree species with the highest rates of CO_2 sequestration: e.g. *Acer platanoides*, *Celtis australis*, *Betula pendula*, *Carpinus betulus*, *Quercus cerris*, *Fraxinus excelsior*, *Ginkgo biloba*, *Liriodendron tulipifera*, *Ulmus minor*, *Sophora japonica*, *Liquidambar styraciflua*, *Tilia cordata*, *Tilia platyphyllos*

Tree species with less efficient CO_2 sequestration: e.g. *Acacia dealbata*, *Albizia julibrissin*, *Cercis siliquastrum*, *Corylus avellana*, *Crataegus monogyna*, *Cupressus sempervirens*, *Fraxinus ornus*, *Ligustrum japonicum*, *Malus spp.*, *Koelreuteria paniculata*, *Parrotia persica*, *Prunus cerasifera 'Pissardii'*, *Prunus serrulata*, *Pyrus calleryana*, *Sambucus nigra*, *Sorbus aucuparia*. (Di-Cara, F., et al., 2020)

2.5.2. Repelling dust and sandstorms:

It has been proven that different types of trees and plants can repel and deposit varying amounts of sand and dust carried by the wind, where a single fully-grown tree can absorb 978 kg of dust annually, which is deposited on its leaves, stump and trunk and then falls to the ground with rainfalls or wash. (Taha, T., 2009) Dust is removed from the atmosphere when it contacts a surface through the processes of sedimentation, diffusion, turbulence, leaching and covert deposition. (Qualivivia Project, A8, G3, 2011)

The quantification of the benefits of urban trees in removing dust pollution was reviewed by (McPherson et al., 1994) for the city of Chicago, where trees removed approximately 234 tons of PM₁₀, resulting in a 0.4% improvement in average hourly air quality. Likewise, (Nowak, D., et al., 1997) estimated that trees in the city of Philadelphia improved air quality by 0.72% in terms of reducing fine dust, particulate matter.

2.5.3. Air Purification from harmful compounds:

Afforestation works on the dispersal of pollutants and the decrease in air pollution rates. The concentration of pollutants decreases with the increase in the percentage of open green areas, while tree barriers between residential and industrial areas filter the air to a great extent. In addition, plants absorb different types of toxins in the polluted atmosphere, and these toxins often turn into non-toxic substances. (Taha, T., 2009)

2.5.3.1. Removal of Environmental Pollutants

Trees in cities affect air pollution through two important processes: **Directly**, through dry deposition with which atmospheric pollutants (both gaseous and particulate) can be removed from the air. **Indirectly**, through the cooling of the ambient temperature and therefore the slowing down of the smog formation process (Akbari, H., 2002; Qualivivia Project, A8, G3, 2011)

Trees and shrubs are capable of effectively remove various pollutants generated by human activities, thus avoiding their spread into the environment and ensuring air purification. The removed amount of pollutants varies according to tree size. Average reference values could be taken for different diameter classes from the bibliography (Nowak, D., 1994; Ferrini, F., 2009) and in case of unavailable diameter classes, a linear regression analysis could be made to obtain the missing data based on those available. (Di-Cara, F., et al., 2020)

Quantity of pollutants (PM₁₀, O₃, NO₂, SO₂, CO) absorbed or retained by Park's vegetation:

$$\text{Pollutant absorbed by species diameter category (kg/year/plant)} = t \times n \quad \text{Equation (M)}$$

where t annual absorbed pollutant/tree for each diameter category in kg

n number of plants present for each diameter category

$$\text{Total Pollutant absorbed by species (kg/year)} = \text{sum of all diameter category} \quad \text{Equation (N)}$$

$$\text{Total Pollutant absorbed by Park (kg/year)} = \text{sum of all species} \quad \text{Equation (O)}$$

2.5.3.2. Compensation for Pollutants Emitted into the Atmosphere

Similar to the compensation of CO₂, the number of trees needed to absorb or suppress various released pollutants in the atmosphere by various human activities is estimated as follows:

$$\text{No. of trees required/ area m}^2 = \frac{\text{Total Pollutant emissions}}{\text{average annual seized / tree}} \quad \text{Equation (P)}$$

A healthy, full-grown tree absorbs on average about 0.42 kg of pollutants per year (considering only O₃, NO₂, SO₂ ePM₁₀). (Di-Cara, F., et al., 2020) The highest performing species have an average net absorption value of 1.14 kg / tree / year. While other species are less efficient in various pollution sequestration, where the same consideration mentioned in the less efficient CO₂ species and their valuable use should be taken.

Tree species with highest rates of pollutants removal: e.g. Acer platanoides, Acer pseudoplatanus, Liriodendron tulipifera, Magnolia grandiflora, Corylus columna, Fraxinus excelsior, Fraxinus oxycarpa, Platanus x acerifolia, Quercus ilex, Quercus robur, Salix alba, Tilia platyphyllos, Tilia tomentosa, Ulmus parviflora, Ulmus procera.

Tree species with less capable of reducing air pollutants: e.g. Acer campestre, Acer negundo, Cercis siliquastrum, Koelreuteria paniculata, Ligustrum japonicum, Malus spp., Melia azedarach, Morus spp., Ostrya carpinifolia, Prunus cerasifera 'Pissardii', Pyrus callieriana.. (Di-Cara, F., et al., 2020)

2.5.3.3. Measurement of NO₂ uptake by plants:

In a study to measure the rate of nitrogen dioxide uptake by potato plants using laboratory methods, potato plants were exposed in special basins with a continuous stream of NO₂. It was assumed that these basins do not absorb gas, and a plastic cover has been placed on the surface of the soil in which the plant grows to prevent the gas from being absorbed by the soil. At the end of the experiment, it was found that the concentrations of NO₂ concentration decreases, if passes through the plants, which indicates that the nitrogen dioxide gas has been absorbed by the plant. The absorption rate of NO₂. was estimated by the equation: (Taha, T., 2009)

$$Q_{Cin} - Q_{Cout} - Vr = 0$$

where Q_{Cin} → NO₂ concentration in µg/m³
In the event of gas entering the plant basin.

Q_{Cout} → NO₂ concentration in µg/m³
In the case of gas out of the plant basin.

V → Volume of the experiment vessel

r → Gas absorption rate in µg/m³

Experiment's Results showed linear and incremental relationship of nitrogen dioxide absorption rate that is accompanied by an increase in NO₂ gas concentration, with a ratio between Q_{Cin} and Q_{Cout} ranged between 26% and 40% and NO₂ uptake ranged between 0.3 to 0.73 Mg/m³.s, increasing with the increase of amount of NO₂ gas entering (Taha, T., 2009)

2.5.4. Soil Protection:

Stabilization and cohesion of soil particles and protection from erosion and damage. Afforestation positively affects the soil stabilization process and acts as a deterrent to erosion and repels dust-laden winds that destroy plantings and agricultural projects, on the other hand, the vegetation cover preserves the soil from erosion due to the intense winds. The root system of trees absorbs exceeded groundwater limits, protecting agricultural soil from damage. (Taha, T., 2009)

2.5.5. Enhancing Human Health:

In addition to the importance of plants and vegetation in religious beliefs, vegetation leads to the provision of beautiful breathtaking scenery and the creation of a picturesque atmosphere that enrich joy, pleasure and optimism to the soul, especially in the city, creating a suitable environment for community comfort, recreation, sports and leisure. It also enhances health and social levels and provides a stimulating atmosphere for creativity and innovation. Sidewalk's plantations offer shading for better pedestrian experience, especially in cities with hot, sunny summer weather. (Taha, T., 2009) It is also utilized to create roadside barrier to control pedestrian's exposure to air pollution, where the optimum structure is context dependent, considering topography of the built environment, i.e.: open road or built-up street canyon, the influence of selected plant species should be considered. (Barwise, Y., et al., 2020)

2.5.6. Air Cooling:

Urban greenery affects the climate by reducing extreme thermal events, i.e., air cooling and improving heat island effect, mainly through direct shading and the evapotranspiration process. (Qualivivia Project, A8, G3, 2011) Green areas can reduce the High Temperature in summer by at least 5-6 degrees Celsius, raise the minimum temperatures in winter, and raise the relative humidity in dry season by 5-20%; when applying appropriate distribution methods for green areas and appropriate plants selection. As the radiation degree in bare areas that lacks vegetation, is much higher than in covered areas, because the plants repel direct sunlight and absorb part of it, thus lowering the maximum temperature to a great extent. (Taha, T., 2009)

Using both evergreen and deciduous plants during the warmer season can help reduce cooling costs through shading and evapotranspiration. Evergreen trees can also reduce the need for heating during the winter as they block winds, although this beneficial effect can be partly diminished by excessive shading from the sun, Furthermore, reduced temperatures can slow down the chemical reactions that produce secondary pollutants. (Brack, C.L., 2002; Qualivivia Project, A8, G3, 2011)

Calculation of the Air Temperature Drop

Besides the advantages of trees in providing shade through their canopies, they are also capable through the transpiration process to convert solar radiation into latent heat, consequently, indeed contribute to the temperature reduction of the urban context. Basically, perspiration is the main source of latent heat in cities, where most surface is covered with impermeable materials. (Konarska, J. et al., 2015; Di-Cara, F., et al., 2020)

The latent heat formula can be used to determine the **mass of air that is cooled by one degree** from the amount of energy indicated in some literature (through perspiration, 800 m² of soil with a tree cover of 30% can absorb 1.2 million kcal in one year) (Ferrini, F., 2009) The mass value could be then converted into volume by dividing it by the air density. (Di-Cara, F., et al., 2020)

$$\text{Specific Heat } Q(\text{kcal}) = [m(\text{kg}) * c (\text{kcal/kg } ^\circ\text{C}) * \Delta T(^{\circ}\text{C})] \quad \text{Equation (Q)}$$

$$\text{Mass volume} = \frac{\text{The mass value}}{\text{density of the air}} \quad \text{Equation (R)}$$

For better understanding, Calculating the volume of air occupied by an apartment of 100 m² (on average 300 m³), considering the volume of air within the canopy of the plants in a hypothetical nursery of 0.29 km² absorb 435 million kcal per year. This amount of energy subtracted allows the lowering of 1°C to an air volume equal to 1479 million cubic meters. This volume corresponds to that of about 5 million apartments of 100 m²; or to that of 1020 nurseries of 0.29 km². The same amount of energy subtracted leads to a decrease of 5°C of a volume of 296 million cubic meters of air, which corresponds to 986 thousand apartments of 100 m² or 204 nurseries of 29 km². (Di-Cara, F., et al., 2020)

2.5.7. Reducing Evaporation:

Evaporation rate depends on several factors, including wind velocity, air temperature and relative humidity. Since afforestation and green-screen lead to a reduction in wind speed and high temperature and an increase in relative humidity, it thus reduces evaporation compared to the bare areas. (Taha, T., 2009)

2.6. Biodiversity; Fauna & Flora

The Convention on Biological Diversity (CBD) defines biodiversity as “the variation among all sources of living organisms, including, but not limited to, marine, terrestrial and further aquatic ecosystems and the ecological communities they belong to; including variety within species, between species and diversity of ecosystems.” to rephrase it, it is the diversity at all levels of life on Earth, from genes to global groups of the same species; from species complexes that share the same small habitats to global ecosystems. (Secretariat of the CBD, 2006)

2.6.1. Fauna

One of the main types of CWs are Constructed wetlands for habitat creation, which are systems intended to provide a habitat for wildlife. With a main goal of reaping the great environmental benefits of CWs, not just their function of treatment (Knight, 1997). The existence of water and plants is the main characteristics of CWs which creates a well-suited ecological habitat by appealing wildlife, particularly birds, and by creating a green space. There are generally four main types of CW: (a) Ponds, with a suitable and enough depth for fish; (b) Marshes, basically flat bodies of water with herbaceous vegetation; (c) Swamps, mainly including woody vegetation; (d) Temporary wetlands that collect water seasonally. These systems could also be utilized as a supplier of food and fiber, as well as general recreational areas (Knight, 1997; Stefanakis, A., et al., 2014)

2.6.1.1. Microorganisms

Wetlands' main feature is that their roles are mainly regulated by microorganisms, *including bacteria, fungi, yeast, protozoa and crustacean algae*, and their metabolism (Wetzel, R., 1993). Microbial biomass is an important sink of organic carbon and various nutrients. Microbial activity includes: (Davis, L., 1995)

- Converts many organic and inorganic substances into harmless or insoluble substances
- Changes the reduction/ oxidation of substrate conditions, hence, impact the wetland processing capacity
- Participates in the recycling of nutrients.

Some microbial transformations require free oxygen (aerobic), while others occur in the absence of free oxygen (anaerobic), while various bacteria species are facultative anaerobic, which can function under both aerobic and anaerobic conditions according to altering environmental conditions. Microbial species adapt to changes in the supplied water; they can spread rapidly when introduced with appropriate energetic materials, while with inappropriate ambient environments, they mainly become inactive and can remain inactive for years. (Davis, L., 1995) CW's microbial population can be impacted by toxic substances, i.e., pesticides or heavy metals, so precautions should be followed to avoid introducing these chemicals in harmful concentrations. (Davis, L., 1995)

2.6.1.2. Animals

CWs offer habitat for a large variety of invertebrates and vertebrates. (Davis, L., 1995)

- **Invertebrate:** the most important concerning improving water quality and play various ecological roles;
 - Worms and insect, contribute to the treatment process through wastes break down and organic matter consumption. While various insects' aquatic larvae, during their larval stages, consume vast quantities of material, which can extend for many years.
 - Dragonfly nymphs are important predators of mosquito larvae.
- **Vertebrate species:** CWs also attract a wide variety of:
 - Mammals, amphibians, birds, and turtles.
 - Water birds and waders, which includes teal (mallards), wood duck, green-winged teal, moorhens, bitterns and great blue and green herons.
 - Snipe wading birds, marsh wrens, red-winged blackbirds, red-tailed hawks, bank swallows, northern harriers' food or nest in wetlands.

2.6.1.3. Biodiversity of fauna

The irregularity in terrain appeals more species as the varying depths create distinct conditions that suit the preferred feeding habits of a wide variety of bird species, where some streams connect water depths with vertebrate species, providing general guidance on the design. So, it is advantageous to provide some shallow-water areas and other deep-water areas in wetlands, as landscapes with diverse or complex components ensure a better visual impact and overall impact. (Bendoricchio, G., et al., 2000)

2.6.1.4. Animal pests

Some Fauna can be problematic in wetlands, for example: (Bendoricchio, G., et al., 2000)

- Types of fish, such as carp, may lead to severe turbidity affecting the wetland performance, while wetland drainage can make carp harvesting easier.
- Some birds can cause problems while foraging seedlings, which can cause problems while the plants are established.
- Nutrias and muskrats can create tunnels along banks leading to problems with banks' stability and hydraulic impermeability. (Bendoricchio, G., et al., 2000)

2.6.2. Flora (Vegetation)

2.6.2.1. Vegetation

CW should incorporate both vascular plants (higher plants) and non-vascular plants (algae), as algae's photosynthesis improves levels of dissolved oxygen in water, which sequentially impacts nutrient and mineral interactions, while vascular plants contribute to wastewater treatment in several ways: (Davis, L., 1995)

- Stabilizing the substrates and controls the directed flow
- Slowing the velocity of the water, hence, allowing settlement of suspended matter
- Absorbing nutrients, carbon and trace elements and integrating them into the tissues of the plant
- Transporting gases among the atmosphere and sediments
- Oxygen leakage from subsurface vegetation structures creating oxygen-rich microsites in the substrate
- Providing microbial attachment sites through their stem and root systems
- Creating wastes after dying and decomposing.

CW mostly include emerging vegetation, which are non-woody plants growing with roots in the substrate and stems and leaves protrude from the surface of the water. The most popular types used involve reeds, cattails, bulrushes and several species of broad-leaved. (Davis, L., 1995)

2.6.2.2. Biodiversity of flora

It is desirable in wetlands to use multiple forms of vegetation because they are method of physical habitat, providing a variety of food sources, and thus increase the aquatic organisms' diversity. This habitat conditions' variety will also form wetland-dependent birds' diversity. Wetlands should be moderately shaded with partial planted cover on their banks as aquatic diversity in riverine wetlands is increased by moderate shading. The combination of vegetation, water and the coastline length are directly related to the diversity of bird species, where the water-plant contact areas provide cover for waterfowl breeding. For many species, several classes of vegetation are usually necessary for food, lodging, nesting place, shelter and protection from predators: integrated areas should be created from different plant classes. Generally, the planting of two or more crops (policultures) are preferred over monocultures, which have a higher chance of invasion of weeds, destroying parasites, and disease occurrence. (Bendoricchio, G., et al., 2000)

Wetland morphology is a crucial factor in determining the viability of macrophytes; to ensure their maximum growth, the wetland should have some characteristics such as: shallowness, offering shelter, soft soil, and not shaded. To ensure the spread of vegetation, CWs' high humic soil and sandy components offer easier growth for the tuberous runner and the colonization and plant's growth is faster. The number of vertical layers contributes to the diversity of birds that inhabit the wetlands. The number of offered niches for birds breeding, feeding, and covering is increased by the complexity of vegetation on the vertical axis. Vegetation favored by desirable waterfowl species should be enclosed in at least 10% of the wetland, with at least about 5000 m². (Bendoricchio, G., et al., 2000) In city plants, to ensure adequate specific diversity and ensure that plants are not subject to attacks by insects or diseases, the urban vegetation should contain no more than 10% of each single species, no more than 20% of species of the same genus, and no more than 30% of species of the same family. (Qualivivia Project, A8, G3, 2011)

Vegetation of wetlands offer protective habitat, nutrients source and temperature relief for fish through shade; However, vegetation that is too dense can also be harmful: unvegetated canals, ponds or any open water zones are required for the fish to move. Although for many aquatic organisms the hot temperature is a restricting factor, it can be controlled through hanging vegetation shades, as well as through deep ponds and running water, the open zones of water and canals without vegetation cover should meander while short circuits and dead zones should be avoided. To ensure a diversity of habitats, some areas should exist with higher velocity. (Bendoricchio, G., et al., 2000)

2.6.2.3. Role of vegetation in constructed wetlands

Vegetation plays various important roles in CWs such as: (Bendoricchio, G., et al., 2000; Hoffmann, H., 2011)

- Providing Oxygen to sediments through roots and rhizomes to survive in anaerobic conditions,
- Part of this oxygen is offered for microbial processes
- The root system maintains the hydraulic conductivity of the coarse sandy substrate.
- Facilitating growth of colonies of bacteria and other microorganisms, forming biofilms attached to roots' surface and substrate particles, which is supported through submerged parts of plants, Biofilms enable nutrient conversions, organic flocculation, pollutants filtration and promote sedimentation
- Protection from wind through emerging plant parts in addition to providing shade that reduces water temperature and growth of algae
- Increases biodiversity through vegetation diversity
- Providing a variety of habitats for large and small animals (*macro/ microfauna*)
- Providing aesthetic visual contrast through diverse shapes, colors, sizes and textures.
- Proper cultivation boosts wetland's performance, increase habitat value and improve its visual aptitude
- **Mosquito control:** Mosquito problems in wetland mainly result from excessive organic pollution, its control regulations include using biological controls, encouraging predators, maintaining aerobic conditions, avoiding dead zones and mosquitofish stocking (*Gambusia affinis*), which is quite simple in CW if there are perennial flooded zones and avoidance of extremely anoxic situations (Stowell, R., et al., 1985; Steiner, R., et al., 1989; Martin, C., et al., 1989; Dill, C., 1989; Wieder, R. et al., 1989)
- **Odors:** Normally, Wetlands do not encounter challenging odor levels (Kadlec, R., et al., 1996). The odor-causing compounds are usually correlated to anaerobic conditions, which mostly rely on the BOD and the loading of generated ammonia nitrogen and hydrogen sulfide. The possibility for unpleasant odors can be cut by eliminating loading of the oxygen-needing components and by overlapping ventilated basins or channels among wetland components. The cascading downstream channels and structures offer the possibility of removing residual odors before reaching unpleasant conditions.

2.6.2.4. Role of vegetation in wastewater treatment CWs

For the wastewater treatment, all growth forms species is used, the most common however, are robust species of emergent plants, for example the common reed, cattail and bulrush. In addition to the previous roles, vegetation performs a vital role in wastewater treatment, such as: (Brix, H., 2003)

- Providing substrate for microorganisms, one of the essential treatments for wastewater pollutants
- Providing a source of carbon for microorganisms
- Vertical vegetation decreases the flow speed so that solids can dispose
- Absorbing nutrients, but as they age, releasing back of some nutrients to water occurs
- Parts of plant waste that is undecomposed retain some of the nutrients and accumulate in the soil
- Providing oxygen by releasing oxygen from its roots, providing aerobic microorganisms a low soil habitat
- Site-specific value of providing wildlife habitat and aesthetically pleasing wastewater treatment process

In CW for wastewater treatment, the selected species is less vital than the formation of dense vegetation, so any type that grows well can be selected. While for rainwater wetlands, species that mimic the emerging plant communities of adjacent natural wetlands should be selected. Local and native species should be used in both wastewater and rainwater wetlands where they are adapted and likely to perform well for the local climate, surrounding plant, soil and fauna species. (Davis, L., 1995, Nikolić, V., et al., 2009)

2.6.2.5. Selection and role of urban vegetation in CW Parks

Trees in urban environments are subjected to numerous stresses that differ from those to which plants are subjected in rural environments (Saebo et al. 2003). The process of selecting species for use in an urban environment must also consider not only environmental limits (insects, diseases, climate, microclimate and soil) but also cultural, aesthetic and economic factors. While characteristics of plants is a main crucial factor to be studied, the aesthetic factors, growth potential and form, and branch breaking strength are also important criteria in selection. The priority of choice between all these factors depends on the environment in which the plants are to be placed. (Miller 1997) Species' pollution resistance is always relative and depends on: the type of pollutant, its concentration and duration of exposure (dose); the development phase of the plant (age, season, general health conditions), and the physiological age of the leaves; the conditions of growth (soil, climate, nutritional elements); the location (distance from the ground, shielding by buildings or plants). (Qualivivia Project, A8, G3, 2011) Some ornamental species have a very high widespread vulnerability in the population towards some pathogens; therefore the propensity of individual plants to get sick in the future will potentially be very high and will also depend, in nonnegligible way, on the environment in which they will be inserted. (Qualivivia Project, A8, G4, 2011) Nevertheless, urban trees can also have a negative impact on air quality and can also be a source of pollution through the emission of volatile organic compounds of biological origin that contribute to the formation of ozone and indirectly through an increase in pollutant emissions associated with plant maintenance. Tree pollen production is also a source of dust that can have serious health effects for allergy sufferers. (Qualivivia Project, A8, G3, 2011)

Although the various suggested lists of suitable plants were based on their resistance to pollutants (eg Bernatzky, A., 1978; Flagler, R.B., 1998), the experiments were conducted in laboratory conditions (exposure to a high concentration of the pollutant for a short period and in optimal conditions of nutrients, water, light and temperature). In this context, Qualivivia Project in Italy have deliberately conducted a guideline that was done without providing lists or classifications of species to avoid fundamentalisms and considerations based exclusively on a single factor such as the tolerance or ability to remove a pollutant or greater/lesser suitability for a specific polluted environment. In these guidelines, more general indications are provided, such as some macro-characteristics common to several species that are favorable to mitigate the effects of one or more atmospheric pollutants. General characteristics of tree species with respect to their ability to remove pollution can be summarized as follows: (Qualivivia Project, A8, G3, 2011)

- **A tree planted near the source of the pollutant** can be more effective in mitigating pollution
- **Evergreen plants** have generally greater efficiency due to longer foliage life
- **Species with a high total leaf area** are more efficient
- **Species with a prolonged vegetative season** are preferable, early foliation and delayed autumn fall
- **Large, healthy trees** remove more pollution than small trees
- **Fast growing trees** are more efficient and allows the sequestered pollutant to be longer retained
- **The characteristics of the leaves** influence the deposition of pollutants on their surface
- **Avoid the use of sensitive plant to a certain type of pollutant** near the source of that substance
- **Avoid trees with a high rate of VOC** and pollen emissions

Characteristics of selected species for the required type of pollutant removal: (Qualivivia Project, A8, G3, 2011)

1. O₃ Reduction:

- “Low emission” VOC species, can be a valid strategy to help reduce O₃ levels in the city

2. CO₂ Fixation:

- Long-lived species
- Low maintenance
- Medium-fast growing,
- Are large when ripe
- Practicing cultural treatments that increase the longevity and survival of the species
- Minimize the use of fossil fuel for green management
- Use of the removed trees wood to reduce the demand for energy from other sources

3. For Energy Consumption Reduction:

- In hot climates use deciduous plants that shade the buildings (energy saving for cooling)
- In cold climates, evergreen plants shelter buildings from cold winds (saving energy for heating)
- At the management level, a factor that reduces the ability to remove pollution is intense pruning; species that need this practice should therefore be avoided.

4. Dust Removal:

- Effectiveness increases if the leaves and bark are rough, sticky, hairy, resinous or scaly
- Species with very smooth and waxy leaves are not very efficient
- Small or narrow leaves are much more efficient than large ones
- Species with a thinner crown level and more complex structure than the foliage and twigs are more efficient
- Conifers are more efficient than broadleaf trees
- One or more rows of trees have a greater ability to filter the air from dust than an isolated individual
- Efficient windbreaks for the uptake of particulate matter should be made up of species with high, dense and uniform canopy over the entire height
- Windbreaks composed of broad-leaved species such as eucalyptus and many acacias can be effective near dusty roads.

Factors considered in choosing the species according to their ability to grow in an urban environment are:

- **Resistance to diseases and pathogenic attacks;** due to the impossibility of using pesticides in densely populated areas
- **Adaptability to city soils,** which are highly compacted, have low aeration and infiltration capacity, and poor supply of nutrients
- **Adaptability to the local climate**
- **Ability to resist drought**
- **The longevity of the species,** for economic reasons linked to the costs of culling and replanting

2.6.2.6. Shoreline vegetation

Wetland vegetations are capable of reducing wave energy, binding substrates, improving stability of slop and enhancing sedimentation by reducing currents, and hence protecting shorelines from erosion. In addition to their role in providing shade and shelter for fish, they are also a source of invertebrate detritus (a food source for fish), help control temperature of stream water, reduce solar radiation (algae blooms) and drain the bank. Rooted vascular waterbeds, structure of root, height of plant and resistance of vegetation are also vital for protection against erosion. Shoreline stability is provided through the constantly emerging plants by providing frictional resistance to waves and by soil binding at their roots. While trees' weight may counterbalance benefits from roots, as planted trees in a bank can cause its failure in the future. If the range is too long, trees and plants can be used as windbreaks. (Bendoricchio, G., et al., 2000)

2.6.2.7. Aquatic plants used in water treatment:

The presence of aquatic plants in the drains, through their roots, stems and leaves, constitutes a suitable place for the growth of microorganisms that break down the organic matter contained in the water of the watercourse. The gathering of these diverse microorganisms called Periphyton, which is responsible for the natural physical, biological and chemical processes leads to the disposal of approximately 90% of pollutants, while the plants themselves remove between 15-7% of pollutants only, however, the main role of the aquatic plants is being a catalyst for purification processes, in addition, they can deplete heavy metals, albeit at different rates according to the type of plant. The purification process results from a combination of microbial, chemical and physical processes, as plants do not play an important role in the direct removal of some components such as nitrogen and phosphorous or organic materials but contributing to the disposal of 20-10% of them during the growth period of plants. At the same time, the plants give effective support for bacterial growth in the root zone. (AbouElElla, S., 2017)

Various Aquatic plants types are being used in water treatment and are classified into three types: cliffs, submerged and floating plants, which are divided into free-floating and floating with roots extending into the soil. Usually, the plants available in adjacent watercourse are used due to their adaptation to the conditions of the area. (AbouElElla, S., 2017)

a) Emerged Cliff plants:

Aquatic plants that begin their life cycle under water surface, where their roots are firmly embedded in the mud of the bottom or its slope, and the lower part of their stems extends through the water, then the rest of the stem emerges carrying the vegetative system above the water surface. The lengths of its extended stems may reach five meters, while its roots penetrate to a depth of one meter in the soil, and its presence is aided by the low water velocity and shallow depth. In general, it can be said that it grows within the water sector, which does not exceed a depth of one and a half meters and is often found on the slopes of canals and drains, in swamps and shallow ponds. These plants are commonly used for water treatment. This category of aquatic plants includes, *Arundo donax* L, *Echinochloa stagninum*, *Typha* spp., *phragmites australis*, *Desmostachya bipinnata*, *Mentha microphylla*, *Polygonum salicifolium* and *Polygonum senegalense*. (AbouElElla, S., 2017)

b) Submerged plants

Aquatic plants that begin their life cycle under the water surface, grow and live with all its parts inside the water and appears static or oscillating under the water surface. Their stems and leaves contain large air spaces and their propagation is aided by the slow speed and transparency of water. They grow in shallow waters such as drains and shallow parts of lakes and shores of reservoirs. In general, this category of aquatic plants includes several types, such as *Elodea* spp, *Potamogeton nodosus* Poir, *Ceratophyllum* spp., *Zannichellia Palustris*, *Najas* spp., *Myriophyllum* spp., *Potamogeton* spp. and *Vallisneria spiralis* L.. (AbouElElla, S., 2017)

c) Floating plants

Aquatic plants that grow with their root system and part of their stems below the water surface, while their vegetative group floating above the water surface. Its roots may not reach the bottom soil of the watercourse or its lateral inclination, and the plant remains free-moving, with roots hanging under the water surface without reaching the bottom soil, such as the *Eichhornia* and *Lemna*. In this case, the plant is not affected by the depth of the water, but the slow speeds of the water are an encouraging factor for its growth. This type includes plants, such as *Eichhornia crassipes*, *Lemnaceae*, and *Pistia stratiotes*. (AbouElElla, S., 2017)

d) Floating plants with roots extending into the soil

These floating plants' roots may reach the bottom soil or its side slope, where the length of the stem allows the emergence of the vegetative system above the water surface and extending over it like the basil plant. The water depth of such plants ranges approximately from 0.5 to 3 meters. These plants are adapted to the movement of water and therefore have sufficient flexibility in the aquatic medium. These plants are characterized by their short lifespan (30-50 days) and their life cycle can be renewed about four times a year, for example the *Nymphaea* plant. (AbouElElla, S., 2017)

2.6.2.8. Role of vegetation in subsurface flow CWs

Subsurface flow CWs are planted primarily by large vegetation (macrophyte plants), which plays a vital role because they are aesthetically pleasing, serve as animals' habitats such as birds and frogs, and act as a local 'green area'. The most important advantage is the plants' ability to sustain and restore the filter-bed's hydraulic conductivity. It also plays a crucial role in the treatment process, by providing a suitable environment for the growth of microbes and significantly enhances the transport of oxygen to the root zone as part of the filter bed. In addition, dead plant material forms an insulating layer in cold climates, offering a constructive effect on the process of subsurface flow CWs in winter. In the case of reeds, for example, there is a huge network of roots and rhizomes which, because of their ability to carry oxygen from the leaves to the roots, provides great biological activity in CW. For Horizontal Flow Beds, HFBs, an even root distribution in the entire filter layer is important, while for Vertical Flow Beds, VFBs, only an even root distribution in the upper layer (the first 10 cm) is crucial. (Hoffmann, H., 2011)

2.6.2.9. Recommendations for vegetation in CWs

Recommendations for selecting plants for usage in CWs; mostly macrophyte: (Hoffmann, H., 2011)

- Species that are indigenous and local to be used, avoiding exotic and invasive species
- Species growing in natural wetlands or riversides; adapted roots to water saturated conditions
- Species with an expanded subsurface system of roots and rhizome
- Species with tolerance to sudden water loads and temporary drought periods.
- Species should be tolerant to saturated soil and temporary floods, and not constant flooding

Examples of suggested species used in subsurface flow CWs in: (Hoffmann, H., 2011)

Cold climates: i.e., *Phragmites australis* (Common reed), *Typha latifolia* (Broad-leaved cattail), *Glyceria maxima* (reed sweet grass), *Phalaris arundinacea* (reed canary grass) and *Iris pseudacorus* (yellow iris).

Warm climates: for example, Egypt: i.e:

- *Cyperus papyrus* (Papyrus sedge)
- *Cyperus albobristatus* and *Cyperus alternifolius* (Umbrella sedge)
- *Cyperus haspensis* (Dwarf papyrus)
- *Bambusoideae*, *Bambusa vulgaris* (Bamboo, smaller ornamental species)
- *Typha latifolia* (Broad-leaved cattail)
- Species of genus
 - *Heliconia*: lobster-claws, wild plantains
 - *Canna*: Canna lily
 - *Zantedeschia*: Calla lily
- *Pennisetum purpureum* (Napier grass or Elephant grass)
- *Chrysopogon zizanioides* (Vetiver, formerly called *Vetiveria zizanioides* and cuscus grass)

A detailed advantages and disadvantages were discussed by (Hoffmann, H., 2011) and many other plants possible examples can be found in (Brisson, J. et al, 2009)

2.6.2.10. Wetland Plants Harvesting

The controversial point of harvesting vegetation of CWs depends on the plant's growth, if they interfere with activities of operations or maintenance, then they should be harvested. For example, VFB vegetation in warm climates require harvesting on a rate of two years to enable visual inspection of the system of distribution. Differentiating between 'hot-dry' climate and 'hot-humid' climate, a hot-dry climate like Egypt, has a very slow rate of decay of dead reeds accumulating on the surface, while in countries with a hot-humid climate like Brazil, it has a very fast rate, therefore, CW in Egypt requires more harvesting. While to conclude the benefits of harvesting and not harvesting, the following points are to be considered: (Hoffmann, H., 2011)

Benefits of harvesting CWs vegetation involve:

- Nutrients and Pollutants absorbed by the plants are removed from the system
- Easier maintenance tasks for VFBs, due to less plant biomass
- Possible reuse of plant material in the form of straw or fodder

Benefits of not harvesting CWs vegetation involve:

- In moderate Climatic zones, the formation of an insulating layer of dead vegetation material
- If denitrification is important; it provides a carbon source for nitrogen removal
- No change in the ecological performance of wetlands
- Low maintenance requirements

2.7. Water quality

Wetlands are complicated grouping of water, substrate, plants represented in both vascular and algae, wastes which are mainly fallen plant material, invertebrates which are represented mostly in insect larvae and worms and a range of microorganisms which are represented significantly in bacteria. (Davis, L., 1995; Mureşan, M., 2012) A CW is a shallow engineered basin consisting of type of substrate which is mostly soil or gravel and is planted with saturation tolerant types of vegetation. Water ingress is controlled at one end and is allowed to flow above the surface or through the gravel or substrate and is discharged from the other side through a dam or other structure that controls water depth. (Omondi, D. et al., 2020; Davis, L., 1995) For improving water quality, various mechanisms are available that are usually correlated, wetlands adopting these mechanisms are the effective treatment wetlands, these mechanisms include: (Davis, L., 1995; Mureşan, M., 2012)

- Disposition of suspended particulate matter
- Chemical precipitation and Filtration through water contact with litter and substrate
- Chemical transformation
- Ion exchange and Adsorption on plants, substrate, sediment, and litter surfaces
- Degradation, Conversion and Breakdown of pollutants by vegetation and microorganisms
- Absorption and conversion of nutrients by vegetation and microorganisms
- Predation and natural death of pathogens.

2.7.1. Water quality enhancement

Wetlands are mainly used for the restoration of self-cleansing ability of water system ecosystems, through facilitating the decrease of intensities of hanging solids, pathogens, nitrogen, biochemical oxygen need, phosphorous, and other materials. The efficiency of treatment is depending on water retention duration, temperature, incoming pollutants' concentration, distribution of vegetation, depth, light and hydraulic efficiency. (Bendoricchio, G., et al., 2000)

2.7.2. Water storage and flood attenuation

With a well-designed CW corresponding to an effective hydraulic engineering system, it can be used as water reservoirs and buffer zones with high flow velocities. (Bendoricchio, G., et al., 2000)

2.7.3. Recharging of groundwater

By keeping surface water for enough long time in in the wetland it allows water filtration into the underlying sediments and/or base aquifers, supported by a porous soil, this presents the role of wetlands in groundwater recharge. (Bendoricchio, G., et al., 2000)

2.7.4. Evapotranspiration (ET)

The process of combined loss of water due to transpiration of plant and water surface evaporation is called Evapotranspiration. ET in wetlands is an important factor, as the surface area is large in relation to water volume. In addition, while most land vegetation preserve water in hot, dry weather, most of wetland vegetation do not preserve and hence, they are efficient in transferring significant amount of water in the summer from wetlands to the atmosphere. The water loss by ET should not exceed the amounts of the incoming water flow, otherwise additional water is needed to keep the wetlands moist and prevent toxic levels of concentrations of pollutants. In general, the estimation of ET rates fluctuates extensively, in 1990 a suggestion about constantly flooded wetland by the WPCF, *Water Pollution Control Federation*, assumed that the ET can mostly be equivalent to the lake evaporation or about 70 to 80% of the total evaporation values. On the other hand, in another study, it was discovered that dense emerging vegetation decrease total water loss and assumed that water loss through its transpiration is less than that evaporated from open surface water. (Kadlec, J. A., 1993) while other data suggest that the majority of wetlands have an ET equivalent or marginally less than pan evaporation and that those studies with higher ET rates was performed on a very small scale to compensate for edge-effects. (Davis, L., 1995)

2.8. Air Quality

Air pollution is a critical global problem and considered the greatest environmental risk to human health, according to the World Health Organization it is responsible for one in nine deaths each year. (WHO, 2016) It is exacerbated by the expected global population growth (UN, 2017), with intensified urbanization and the climate change effects and weather fluctuations, particularly in urban areas, with high concentrations of pollutants and convergence of prospective sufferers. (Tibbetts, J. H, 2015; Barwise, Y., et al., 2020)

2.8.1. Urban vegetation planting and management strategies to improve air quality

Well-designed CW Parks contribute positively to improve air quality through: (Qualivivia Project, A8, G3, 2011)

- Increase the number of healthy trees; to increase the removal of pollution
- Maintain the existing tree cover; to safeguard the pollution removal rate
- Maximize the use of low-VOC plants; to reduce the formation of O₃ and CO
- Favor the development of large trees; because large trees are more efficient than small trees
- Use long-live species that do not need crop care; to reduce emissions arising from maintenance activities
- Reduce the use of fossil fuels in vegetation maintenance operations
- Plant trees in strategic areas to reduce energy consumption
- Plant trees near parking lots, in densely populated or highly polluted areas
- Supply water to the vegetation; increases the capacity of removing pollutants and reduce temperature
- Avoid species sensitive to pollutants; to promote plant health
- Possibly use the resulting or end-of-cycle woody material for energy production.

2.8.2. Interactions between Green Infrastructure GI and Air Quality at different spatial scales

The cost-effective multifunctionality of GI is demonstrated by several studies, this is represented through the diversity of impacts of ecosystem services that can be achieved or improved through GI includes ambient cooling and microclimate regulation, that brings additional benefits in the reduction of local energy use and related emissions, in addition to rainwater mitigation, mental and physical health improvement, supporting Biodiversity and adaptation and mitigation of climate change. (Barwise, Y., et al., 2020) Vegetation is generally considered to be beneficial for air quality, however, the relationship is complex, the possibly advantageous impacts of vegetation on air quality are generally divided into the processes of dry sedimentation and atmospheric dispersion, the collective effects of these processes are diverse and occur on different scales. (Barwise, Y., et al., 2020) Vegetation performs as a natural barrier between the source and receptor of pollution, efficiently increasing the distance between air pollution and potential sufferers. Porous vegetation barriers act as a passive approach of improving air pollution through the adjustment of the spreading patterns to mimic the achievement of solid barriers. (Gallagher et al., 2015) However, adaptation to the context conditions is required for an efficient barrier design. (Barwise, Y., et al., 2020)

2.8.3. Vegetation structure for different scale context

In street canyons, high and low levels of vegetation can be distinguished, where High-level plants can limit air exchange from above and trap ground level pollution; while it is generally recommended to implement only low vegetation, or only green walls in deep urban canyons, to facilitate both dispersion and sedimentation, despite that increased sedimentation can offset part of the reduction in dispersion which trees may cause in street canyons (***Street Canyon***: Ratio of {height (H)/width (W)}; (*Shallow*: ≤ 0.5 ; *mid-depth*: 0.5–2; *deep*: ≥ 2) General recommendations for physical vegetation structure in open-road and street canyon contexts, can be summarized: (Abhijith, K. V., et al., 2017; Barwise, Y., et al., 2020)

Street Canyon: Ratio of {height (H)/width (W)}; (*Shallow*: ≤ 0.5 ; *mid-depth*: 0.5–2; *deep*: ≥ 2)

2.8.3.1. High-level vegetation,

Trees, with a lifted canopy from the ground level.

- **For Open Road:** woody plants can be used as a continuous barrier that can improve the air quality on the pedestrian side; despite the variation in effects based on wind speed and direction, relative humidity, location, temperature and physical barrier properties; crucial properties include barrier porosity, height and thickness. High and dense plants, with low porosity, are recommended as optimal; Since low density vegetation barriers, high porosity, can decrease wind speed when penetrating gaps, causing pollutant collection in the direction of the wind, while very high dense plants, very low porosity, can limit the removal of pollutant by limiting penetration and forcing air pollutants to flow or recirculate over and around the barrier and accumulating on the wind or source side. The barrier should not have any gaps or breaks; with recommended optimal thickness of 10 m or more, to maximize the available space; with length of barrier extending beyond the area of interest
- **For Street Canyon:** Generally harmful, regardless of composition, as both degree and method of impact on pollutant dispersal are deduced by a relation of ratio (H/W) and wind flow local settings; On the wind direction side of shallow canyons, small trees with open crowns can be placed at a great distance in places where canyon trees are already located or must be replaced. Reducing tree height, stand density, crown density and crown size by selecting the smallest light-crowned species and through pruning and thinning.

2.8.3.2. Low-level vegetation,

Shrubs and hedges, with a beginning leaf cover at or near the ground level.

- **For Open Road:** Previous recommendation for high-level vegetation in open road applies also for low-level vegetation; Shrubs and hedges better form a continuous barrier with trees or should be raised to a height of at least 2 m to reach above pedestrians' breathing height; aligning barriers parallel to and close to the road where low vegetation can reduce pollutants at vehicle typical exhaust heights
- **For Street Canyon:** It is advised to be avoided in the deep street canyons; while in shallow street canyons, air quality can be improved along passageway, but the effect is not obvious; better to have central hedge on both sides of the street; which should extend along the entire street length without joints; Critical factors are shrub porosity and height, as very low shrubs are suggested for canyons of medium depth and bushy (dense) vegetation with an ideal height of about 2m for shallow canyons.

2.8.4. Species selection process for improved air quality

For a simplified steps of the species selection process; the first steps start by **establishing an initial plant list** of species with viability and environmental tolerance, thriving under various known conditions; (Air pollution, climatic, soil, salt and drought tolerance). The second step include **matching use potential to objective**; the plant suitability to urban context regarding plant's morphology; height, crown density and other characteristics, and plant's ecophysiology. In general, for open road conditions, use early successional species; while for street canyons use late successional species. The next step is **refining the list**; through the main points of air pollution exacerbation potential; low BVOC emissions for city-scale and Low pollen emissions for site-specific projects, and the species diversity principle of 5-10% particularly in City-scale. The final step **sorting by site-specific needs or constraints** through a number of points to consider when making the final selection of beneficial plant properties. This includes assessing air quality improvement potential according to type of vegetation; where Evergreen species, with a longer leafy season, is generally more beneficial than deciduous species, with a short leaf season. Other points to consider are LAD, leaf size and complexity and leaf surface features, including smooth or rough texture (trichomes, grooves, etc.), and epicuticular wax amount and composition. Consideration for the site's specific needs or limitations should be respected in each point, i.e., a narrow planting location may require a species with a higher density of crowns, while a site with sufficient space for parallel tree rows to the road allows selection of more open crowns species, expanding the range of possible species and allowing focus on other important traits such as surface features paper. Stomatal characteristics may be of greater importance for gaseous pollutants. (Barwise, Y., et al., 2020)

2.8.5. Important findings and recommendations in improving air quality through vegetation

For improving urban air quality through appropriate vegetation selection in vegetation barriers design, particularly in open road environments, include: (Barwise, Y., et al., 2020)

- The GI can be used for local-scale pollution exposure reduction, but the most effective strategy at all levels is effective control (reducing emissions).
- Analysis of GI and air quality interactions on city-scale can lead to unsuitable planting suggestions, with down-scaling limitations due to the severe heterogeneity of conditions at the local-scale and the reliant on inherent context of the effects of various forms of GI on air quality.
- In street canyons, for the corresponding GI, aspect ratio is critical. In deep street valley ($H/W \geq 2$) recommending only green walls; while in medium deep street valleys ($H / W 0.5-2$), low vegetation of shrubs and low hedges can also be used; and in flat street valleys ($H/W \leq 0.5$), open-crown small trees can also be planted on the leeward side of the valley at a great distance.
- In open road conditions, direct roadside plant barriers of at least 2 meters in height and higher heights should be placed at greater distances from the road in order to protect the flow of pollutants. Where space allows, placement of arrangements of low and high vegetation, for example, trees row over an adjacent fence. The Leaf cover should start from the ground and extend over the entire barrier. recommended Leaf Area Density, LAD, is >3 and <5 , although density should be higher in tight planting sites in order to ensure lower porosity or barrier density with above average.
- Potential GI disadvantages to air quality include not only the tendency of inappropriate forms of the GI to inhibit dispersal, but also the tendency of some plants to release high levels of biogenic volatile organic compound (bVOCs) and/or pollen. Emissions of bVOC are of paramount importance to large-scale planting plans, while pollen emissions must be considered from one site to another.
- Leaf longevity means not only the GI performance annual longevity, but also the longevity of all potentially harmful qualities and sensitivity to environmental stresses such as air and salt pollution.
- Complex, small, and hard leaf is likely to be more effective than less complex, larger and less rigid leaf.
- Preferred features of leaf surface include high density or size of stomata, high content of epicuticular wax (especially in needle-shaped leaves), and qualities increasing leaf roughness (such as grooves, hairs or ridges), though unclear relative importance of diverse leaf surface features and for various pollutants.
- Careful assessment of each plant's suitability for each location is required for application of flexible and efficient GI, including withstanding the associated stresses and the shape of the projected growth.

2.9. Human uses

Wetlands are appreciated by humans for their commercial profitable values (harvesting, pasture, aquatic culture and hunting) in addition to non-consumer values, for example recreations, research, aesthetics and educational and lifelong knowledge values (Kadlec, R., et al., 1996) For the latter uses, wetlands have integrated park-like areas that are appealing and enlightening for excursions and other educational functions. Appropriate design for watching birds, cycling, and exercising should be created. (Bendoricchio, G., et al., 2000) These various human uses and engagement in wetlands, including gratification of availability of recreational areas and a suburban wetland for wildlife and a hunting reserve, can be important drivers of community support for the improvement and protection of wetlands. (Kadlec, R., et al., 1996; Bendoricchio, G., et al., 2000)

2.9.1. Use green to save energy

The Economic return of trees can be estimated = Expected benefits – Expected costs

| | |
|-----------------------|--|
| where Benefits | Power, Air quality, Runoff, Property value... etc. |
| Costs | <i>Planting - Pruning (Removal of leaves / branches / fruits), Irrigation, Repair of artifacts, Legal and administrative fees.... etc.</i> |

Economic benefits of greenery: (Ferrini, F., 2009).

- With an estimation for 100 trees in 40 years to pay off: \$ 231,000 (Benefits \$ 379,000 - Costs \$ 148,000) average 57.775 million / year
- Savings of about 50 billion kwh / year (25% of the total consumed for air conditioning)
- Reduction in electricity consumption and CO₂ emissions by approximately 32 million tons

2.9.2. Access to the site

For a proper community engagement and in accordance with local safety laws, all types of landscaping and parks should include a variety of open spaces that encourage versatility and site experience. Access must be guaranteed for both able and disabled people, with special attention to handicapped and the physically challenged people, where entry requirements for wheelchair users include access integration of ramps less than 1:10 (tracks). (Bendoricchio, G., et al., 2000)

Other important Socio-cultural and Economic impacts in constructed wetland parks are further discussed in Chapter 3, (3.1.1.1. Economic indicators and 3.1.1.2 Social-cultural indicators)

2.10. Climate

In site selection and project planning, climate is significant factor as it influences both wetlands size and type to be used. With the most crucial factor affecting climate during project planning is Location, as latitude determines the ranges of seasonal temperature. In addition to other important climatic factors like precipitation, evaporation, solar radiation, wind speed and evapotranspiration. (Bendoricchio, G., et al., 2000)

During winter and the intensely cold months of the year, the long-term average temperature has proven to be a good assumption of the critical low temperature of water that will occur in a wetland system (Kadlec, R., et al., 1996). For regions where the monthly minimum mean temperature is below zero, it can be expected that the minimum operating temperature in wetlands under ice cover is slightly above zero. (Kadlec, R., et al., 1996). (Bendoricchio, G., et al., 2000)

2.11. Soils and Geology

During planning, the site soil must be distinguished and categorized according to a complicated set of chemical and physical properties. During project design, the most crucial information is related to the depth of seasonally raised groundwater, the depth of the surrounding clay layers, soil composition and chemical structure, especially for construction of bank or for groundwater penetration. In certain cases, the possibility of soil absorption is a design factor, as in metal removal. (Bendoricchio, G., et al., 2000)

2.12. Environmental Impact Assessment (EIA)

EIA, is the process of evaluating and assessing the potential and possible environmental impacts of a particular project, with studies being conducted prior to the project implementation phase to identify the best options for reducing environmental impacts and risks. And address the negatives that are likely to arise before moving on to the implementation step. Consequently, EIA is considered a method for understanding the possible project's environmental impact, being applied to various types of projects, infrastructure, construction, mining and many other; aiming to protect and preserve the environment from any probable risks that projects pose to the surrounding environment, be it land, water, soil, air, etc. (Lexology, 2019)

In another words, EIA is an organized process of predicting, evaluating, identifying, and mitigating the potential impacts of the projects, actions, plans or programs relative to the biological, physical-chemical, socio-economic and cultural components of the total surrounding environment prior to main commitments and decisions being made. (Iyer, V., 2020, Adel, M., et. al., 2019) It is evident that some types of development project exceed beyond the limits of the typical EIA method to a more comprehensive Strategic Environmental Assessment (SEA) method integration (Iyer, V., 2020; Adel, M., et. al., 2019).

2.12.1. Assessment of multifunction constructed wetlands projects:

The major crucial point in assessing the landscape sustainability of multifunctional CW projects, is the interrelations between the various aspects of sustainability that initially result from the multiple functions of these projects. Where the required comprehensive assessment criteria for CW evaluation is not covered by the most common environmental evaluation tools, such as EIA, Environmental Impact Assessment, LCA, Life Cycle Assessment, and SEA, Strategic Environmental Assessment. However, they are the building blocks of reaching a proper evaluation model, and Fig. (8) shows the main standards and factors considered when evaluating multifunctional CW projects. (Garber, R., 2020)

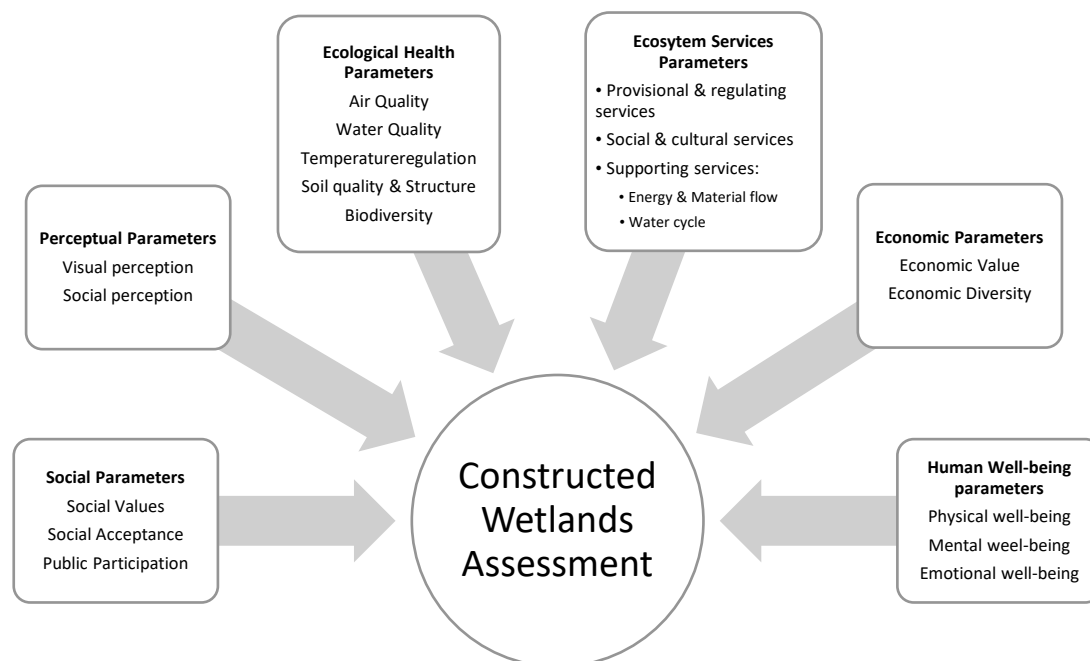


Fig. (8) Conceptual Framework for multifunction constructed wetlands assessment, Source: Garber, R., 2020

2.12.2. Mitigation

Mitigation refers to the reduction or avoidance of described effects, generally, mitigation measures are implemented in response to the results of the impact assessment; It should cover all specified areas, with a focus on: (IISD, 2021)

- **Preventive measures** to stop the impact and hence prevent harm or even achieve positive results.
- **Limiting measures** to reduce impact severity and duration.
- **Compensating measures** for impacts that cannot be avoided or further reduced.

2.12.2.1. Mitigation Measures

Mitigation measures offer a structure to decrease, prevent, control or compensate for potential negative environmental impacts of development activities, aiming to the maximization of benefits and minimization unfavorable effects of the project. These mitigation measures can be preventive, corrective or compensatory measures. (EU commission, 2021) which incorporate compensation for environmental damage caused by the defined effects through substitution, compensation, restoration or other measures. Mitigation measures are a proposed outcome of a repetitive process between the environmental effects prediction and the proposed design impact. Based on the initial findings of environmental impacts, further mitigation measures are included in the project design to confirm the protection of the human, biological, and physical environment. (Côté Gold Project, 2015)

2.12.2.2. Objectives

The main impacts and potential mitigation measures are often land related. Practically all improvement plans incorporate disruption of Earth's surface. Environmental impacts of specific importance could involve wetland drainage, natural areas transformation or expansion into natural hazards exposed areas. (IISD, 2021) Prevention indicates preventing or reducing potential effects before they occur. Corrective actions reduce the impact to an acceptable level. In case of fail of both preventive and corrective measures, compensation measures are taken, to make up for the unavoidable effects. (EU commission, 2021)

The suggested mitigation measures form the foundation for environmental management development strategies and provide plans for the project monitoring, its objectives include: (Côté Gold Project, 2015)

- Protection of the natural, biological, physical and human environment
- Management of wastes
- Handling of pollution and hazardous waste.
- Forming the basis for developing control and monitoring plans.

Monitoring enables the continuous evaluation of proposed mitigation measures efficiency, through the availability of new information based on the monitoring plans, revision of selected mitigation measures is requested if their efficiency is less than expected. (Côté Gold Project, 2015)

2.12.3. Biodiversity in Impact Assessment

Convention on Biological Diversity, CBD, recognize impact assessment as a vital tool in achieving the Convention's goals of Conservation, Sustainable Use and Equitable Distribution. Engaged countries must apply measures for biodiversity protection at various levels: (Secretariat of the CBD, 2006)

- Ecosystems with rich biodiversity, threatened or endemic species of various significance value.
- Existence threatened species or communities
- Genotypes of scientific, economic or social importance.

2.12.3.1. Objectives of biodiversity management

For assessing biodiversity-related impacts, a set of guidelines is provided that relates to the three main objectives of the CBD, which are the **Conservation of biological diversity**, which is concerned with preserving biodiversity by maintaining life support systems on Earth and preserving future options for human development; **the sustainable use of its components**, by securing people's livelihood without risking future options; and the **fair and equitable sharing of benefits** from the utilization of commercial and further uses of genetic resources. The agreement covers all ecosystems, species and genetic resources. (Secretariat of the CBD, 2006)

The ecosystem approach is the most important structure for a balanced tackling of the three CBD goals. The ecosystem approach is a method to the cohesive management of water, land and living assets that fosters protection and sustainable use in a fair manner. Decision making can be very challenging due to the different conceptions of ecosystem values. A distinction can be made between: (Secretariat of the CBD, 2006)

- **Economic values:** (i) Direct income, e.g. from sale of products; (ii) Input to other activities by supplying raw materials; (iii) Indirect value by offering services that unavailability would involve large investments;
- **Social values:** safety, employment, quality of life, health/ social safety, appreciate animal and plant life
- **Ecological values** or future values, conserving biodiversity and its potential unknown future use.

2.12.3.2. Assessing impacts on biodiversity

The Millennium Ecosystem Assessment (MA) describes ecosystem services as "the advantages that humans derive from ecosystems". To maximize positive impacts on ecologies and reduce negative impacts, reasons/ purpose of change, whether natural or man-made factors, must be evaluated. Impact assessment mainly addresses human-made drivers of change. However, natural drivers are important, because they determine the background trends or variations against which man-made changes are assessed. The impact assessment process is designed to consider wide variety of factors that cause changes in biodiversity: (Secretariat of the CBD, 2006)

- **Direct drivers of change**, identifiable and measurable changes including: land-use and land-cover changes; extraction, harvesting or species removal; Fragmenting and isolation; external inputs like effluent, emissions and chemicals; introductory of invasive or genetic modified species; restoration
- **Indirect drivers of change**, which may affect direct drivers; Demographic, socio-political, cultural, economic and technological processes or interventions.

2.12.3.3. Biodiversity principles for impact assessment (Secretariat of the CBD, 2006)

No net loss. Further biodiversity loss must stop, both quantitatively and qualitatively. This means that irreparable loss of biodiversity must be prevented and loss of other biodiversity must be compensated (both qualitatively and quantitatively). For example, the loss of ecosystem service can be irretrievable, but in some cases, it is expected that it can be 'replaced' by proper technologies. Wherever possible, chances to improve biodiversity should be adopted and recognized.

The precautionary principle requires a risk-averse approach and caution is applied in unreliable predictable impact cases and/or where there is doubt about the mitigation measures effectiveness. In case impacts on key biodiversity resources cannot be determined with sufficient confidence, action will either be paused until availability of sufficient information, or the worst possible scenario for impacts on biodiversity will be adopted and the suggestion that application and management are designed to reduce to an acceptable level. (Unequal application of the principle must be prevented, e.g. if social interests are high and vulnerable biodiversity is insignificant, e.g. not endangered or replaceable).

Local, traditional and indigenous knowledge is utilized in impact evaluation to offer a comprehensive and reliable outline of biodiversity issues. Exchanging views with stakeholders and experts are significant components of this evaluation, and information on biodiversity is strengthened.

Participation. Sharing with various groups or individuals in a community that have an interest in the conservation and biodiversity use. As a result, only through stakeholders' negotiation, assessment of biodiversity and ecosystem services can be fulfilled, therefore, there is a role for stakeholders in the impact assessment process.

Chapter 3: Environmental Assessment Tool

Introduction

This chapter is focusing on the development a conceptual framework as a base for the selection and sorting for a number of indicators for the sustainable development of landscapes for CW parks. For assessing the CW Parks performance as a multifunctional sustainable landscape project, urban sustainability indicators are set to examine the links between environmental, economic and social aspects and their mutual influences. For this purpose, the proposed indicators are evaluated in relation to the UN SDGs (United Nations Sustainable Development Goals), National SDGs in addition to performance-based assessment tools for CW projects for wastewater treatment.

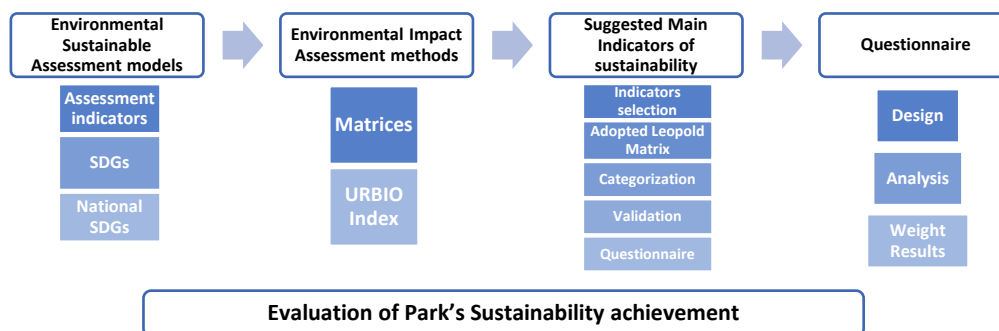


Fig. (9) Chapter 3, Methodology and structure, Source: Author

3.1 Environmental Sustainable Assessment models:

Cities consume 75% of the world's resources even though they cover only 2% of the Earth's surface. They are a primary reason of climate change and loss of biodiversity and ecosystem services. For this reason and for the future of the Earth, greater attention should be paid to sustainability in the planning, construction and management of urban areas. (Müller, N. et al. 2016) Building sustainability certification guidelines and Environmental performance assessment tools have existed for more than two decades and have been implemented worldwide; (Lee, H.-S., et al., 2020) such as “LEED” in the USA; Leadership in Energy and Environmental Design (USGBC, 2022), “BREEAM” in the UK; Building Research Establishment Environment Assessment Method, “CASBEE” in Japan; Comprehensive Assessment System for Built Environment Efficiency, “Green Star” in Australia, “Sustainable Building” in Germany (DGNB, 2009; DGNB, 2022) and recently “GPRS” in Egypt; Green Pyramid Rating System. Comparably, for landscape, green space and park design, there are still insufficient similar tools, although there are researchers advocating the urgent need for designing similar sustainable landscape assessment tools. (Müller, N. et al. 2016).

Consequently, and with this increasing awareness of the significance of the city/neighborhood levels of environmental issues and with the needs of integrative sustainable development, this has created an urgent need for an assessment tool of landscape sustainability that is independent of the current green building assessment system. (Lee, H.-S., et al., 2020) Distinct landscape assessment systems were established through the global sustainability assessment systems. The first tool to measure green spaces sustainability was developed since 1996 in Great Britain with the “Green Flag Award” (GFA 2016). Later, the Sustainable Sites Initiative was developed in the USA since 2005 (SITES, 2016). (Müller, N. et al. 2016) SITES has been applied for the assessment of the landscape sustainability aspects of the project’s site independently of the buildings, resulting in a further integrated sustainable design, whether during the development planning or management planning phases of the project (Lee, H.-S., et al., 2020) The two assessment tools focus on certifications, are complicated and expensive, and do not reflect all aspects of sustainability. A German research project to assess the external facilities of federal government properties was recently established (Robati, M., et al., 2021) and the German Research Platform Landscape “FLL” began developing an accreditation system in 2015. (Müller, N. et al. 2016).

Achieving human well-being and improvement of the quality of life are the main purpose of sustainable landscape projects. For that, the project merges and balances the dimensions of environmental, economic and social sustainability. Constructed wetland, CW, projects are water treatment systems that use natural processes and mechanisms to avoid destructive impacts, unnecessary energy consumption while introducing new sustainability criteria for environmental-friendly water treatment process. (Stefanakis, A., et al., 2014) Like other urban projects, there is a global necessity to assess the contribution of CW projects to the Sustainable Development Goals, SDGs. For the past years, attempts for sustainable assessments have grown exponentially, such as; Health Impact Assessment, Social Impact Assessment, Urban Material Flow Analysis and Ecological Footprint. Yet, adapted evaluation tools are required for individual projects for adequacy in evaluation approaches. (Robati, M., et al., 2021) Which is exactly the case with multifunctional CW projects, in which environmental as well as social and economic factors must be considered. Hence, creating an assessment model for the evaluation of CW parks landscape sustainability aspects is the main objective of this chapter. Aiming to propose logical sustainability indicators that systematically assess a wide range of CW park sustainability criteria as multifunctional sustainable landscape projects. Also proposing appropriate metrics and assigning relevant weights for each indicator and sub-indicators.

3.1.1 Assessment indicators of CW parks:

The state of a specific system in relation to a particular concept is described or reported through suggested parameters known as Indicators. (Pavlovskaia, E., 2014) It is basically a brief measurement that delivers information about a state or change in the measured system. (Fiksel, J., et al., 2012) In this context, the indicators should be easily applicable, clearly articulated and relevant to the general concept required by the assessment. (Pavlovskaia, E., 2014) Subsequently, it is crucial when selecting indicators, to consider how they will be perceived and interpreted so that they are consistent with their intended use. (Fiksel, J., et al., 2012) Sustainability indicators allow for assessing the system fulfillment to the sustainability criteria using quantitative and qualitative assessments tools. (Pavlovskaia, E., 2014; NRC, 2010) A set of fundamental criteria should be considered when assigning specific indicators and their relevant measures, (National Research Council, NRC, 2010) such as:

- 1- Accuracy in reflecting the presented process or function
- 2- Sensitivity in sensing changes through lifetime and various systems
- 3- Practically measurable regarding time, cost and required level of skills
- 4- Comprehensible and relevant to expected users

There is an increasing need to understand and study how CWs work, and to develop systems to monitor their performance, since they are considered as an alternative nature-based method of wastewater treatment. (Ezeah, C. et al., 2015) In the sense of comprehensive understanding of sustainability, sustainable landscape projects must attempt to use available ecosystem services efficiently and to fulfill social and economic needs while taking future needs into account and thus to guide decision-making. (Bond, A. et al., 2012). Landscape indicators should consider the three pillars of sustainability; environmental, social and economic aspects simultaneously and coherently with an important new pillar which is the aesthetic value of the project (Selman, P., 2008). As a context-driven process, the sustainability assessment should be designed on a case-by-case basis (Bond, A. et al., 2011). Indicators for a multifunctional landscape development include a holistic approach regarding the integration of ecological, economic, social-cultural, political and aesthetic impacts. (Çiftçioglu, G., et al., 2015)

3.1.1.1. Economic indicators

The project's ability to bear its own costs and offset the benefits is "Economic sustainability". (Balkema, A. et al., 2002) Cost, maintenance and labor are the key indicators considered for the CW projects (Rai, P., 2012) It should consider feasibility and long-term process of the project according to local standards, especially in developing countries. (Zakaria, Y. et al., 2021) Practically, when choosing a technology in projects, the economic indicators are often crucial. The most frequently used indicators are certainly the investment, the operating and maintenance costs. While affordability, cost-effectiveness and workload are developed indicators. (Balkema, A. et al., 2002)

3.1.1.2. Social–Cultural indicators.

Despite being hardly adopted because they are difficult to measure precisely, socio-cultural indicators are very crucial in the application of technology while it depends on the community acceptance as these indicators relate to the directly or indirectly involved end-user, indicators could be: (Balkema, A. et al., 2002)

- **Community Acceptance and perception** of the project according to culture, heritage or believes
- **Expertise requirement** of the technology for installation or operation
- **Stimulation of sustainable behavior** by tailoring technological design or enhance the end-user's awareness, participation and responsibilities
- **Institutional requirements** fitting to community infrastructure

One of the aesthetic socio-cultural indicators is the **Sense of place**, which could be assessed by the existence of various areas of outstanding beauty, heritage sites, sacred sites, and cultural centers. (Çiftçioğlu, G., et al., 2015) The aim of the socio-cultural indicators is to ensure the social, cultural and spiritual needs of people in a reasonable way with stability in human morals and relationships, based on people's need to interact, develop themselves and organize their society (Balkema, A. et al., 2002)

Another impact is the **Community aesthetic perceptions and expectations**, where the aesthetic pleasure is gained from the landscape. Aesthetic experience is gained through active and passive recreational activities, and by increased knowledge and awareness about landscape structures and functions. This visual quality of a landscape assessed by how it is perceived by the observer and is defined as the "relative aesthetic excellence of a landscape" (Çiftçioğlu, G., et al., 2015)

3.1.1.3. Environmental indicators

Maintaining the natural environment to support long-term development through the supply of resources and the take up of emissions, leads to protection and effective consumption of environmental resources. (Balkema, A. et al., 2002) The landscape is changing rapidly and constantly, especially in highly urbanized areas leading to a considerable loss of biodiversity (Environmental), cultural landscape features and sense of place (Socio-cultural). (Çiftçioğlu, G., et al., 2015) The ability of environmental functions to maintain a human lifestyle is environmental sustainability (Balkema, A. et al., 2002) There seems to be an agreement on environmental indicators in most studies, where the **optimal use of resources** is usually applied as an indicator, especially regarding water, nutrient and energy, as well as the **land area required, Soil fertility** and **biodiversity** that are usually used. (Balkema, A. et al., 2002)

An important part of landscape is Soil, with its direct impact on biodiversity, flora, fauna and flora. Soil fertility represent the soil quality which is the ability of a particular type of soil to function within the confines of a natural and managed ecosystem. Soil quality is particularly crucial for sustainable land management (Çiftçioğlu, G., et al., 2015) Another set of environmental indicators focuses on **emissions**, for example the quality of discharge, sludge, common wastewater and gaseous emissions. (Balkema, A. et al., 2002)

Atmosphere is an integral part of the landscape. **Air quality** is correlated to vegetation and the components of green spaces, therefore, growth in these factors contributes directly to air quality and for achieving such results, two main topics should be addressed; first is emission reduction (from transport and industry) and the second is the creation of more green spaces (e.g. urban forests and roof gardens). (Li, X., 2003) **Wildlife species** is also an important indicator and has an important role in natural ecological processes, the landscape fragmentation and change in land use have a negative impact on the species' abundance and distribution of populations. (Çiftçioğlu, G., et al., 2015)

3.1.2 Sustainable Development Goals (SDG's)

The 2030 Sustainable Development Agenda was adopted by the UN General Assembly in 2015, defining 17 SDGs with long-term transformative targets that balance all pillars of sustainability coherently. (Dickens, C., et al., 2019) This study selected the sustainable resources employment and the natural ecosystems protection related SDG Targets and their respective indicators. The most appropriate Goals and Targets for implementation in the CWs assessment process are found to be:

Goal 6 Ensuring water and sanitation availability and sustainable management, particularly:

Target 6.3, Improve water Quality, untreated water reduction and safe reuse and recycle of Wastewater

Target 6.4, In regard to water scarcity, increase water consumption efficiency

Target 6.b, In relation to community participation in water and wastewater management improvement

Goal 7, Ensuring access to affordable, reliable, sustainable and modern energy, particularly:

Target 7.3, Energy efficiency improvement

Goal 8 Ensuring sustainable and integrated economic growth, particularly:

Target 8.4, Improve resource consumption and production efficiency

Goal 9, Ensuring resilient infrastructure, inclusive sustainable industrialization and innovation, particularly:

Target 9.1, Develop sustainable and resilient infrastructure for economic growth and human well-being

Target 9.4, Improve infrastructure, resource-use efficiency and adopt clean nature-friendly technology

Goal 11, Ensuring inclusive, safe, resilient and sustainable cities and settlements, particularly:

Target 11.6, Reduce negative environmental impacts, mainly air quality and waste management

Target 11.7, Enable access to integrated and accessible safe green areas and public spaces

Goal 12, Ensuring sustainable patterns of consumption and production, particularly:

Target 12.2, Develop sustainable natural resources management

Target 12.4, Management of wastes and reduce their adverse impacts on human health and environment

Target 12.5, Reduce waste generation by avoiding, reducing, recycling and reusing

Goal 13, Taking crucial actions to combat climate change and its impacts, particularly:

Target 13.2, Integrate climate change management strategies into planning at different levels

Target 13.b, Mechanisms for effective climate change planning and management boosting

Goal 15, to maintain and stimulate the sustainable use of terrestrial ecosystems, particularly:

Target 15.1, Sustainable use of global and national freshwater ecosystems and their services

Target 15.3, Combat desertification and promoting degraded lands and soils restoration

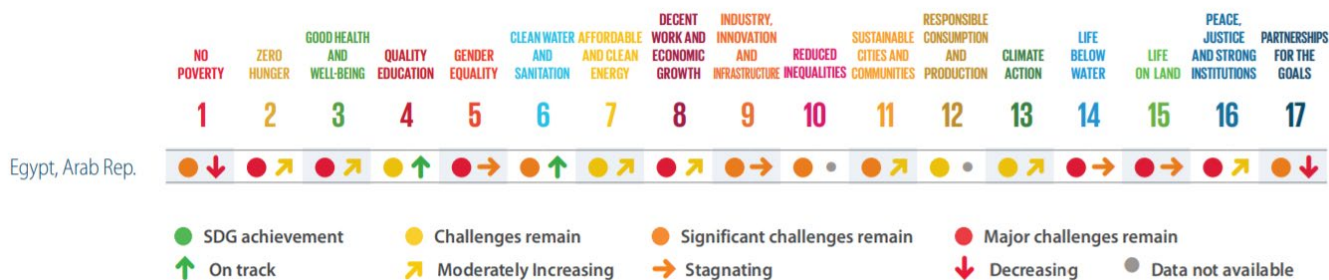
Target 15.9, Integrate principles of ecosystems and biodiversity into national strategies and local plans

Source: UN, 2015

3.1.3 National SDG's

The Sustainable Development Report 2021 (SDR2021) presented data on Egypt' performance against the SDGs, including the sixth edition of the global SDG Index and Dashboards. It complements efforts conducted by national statistical offices and international organizations to collect and standardize SDG indicators. (SDR2021, Sachs, J., et al., 2021) According to the 2021 SDG Index for assessment country's overall performance on the 17 SDGs, giving equal weight to each Goal, Egypt ranked the 82, with a score of 68.6, with the following performance details:

2021 SDG dashboards (levels and trends) for Egypt

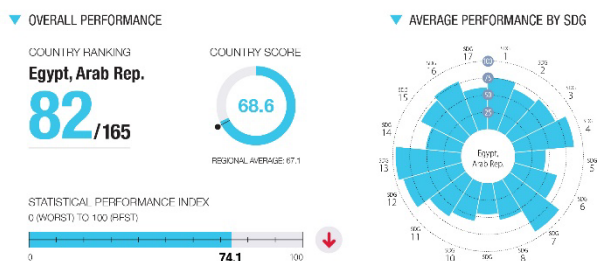


Dashboards: ● SDG achieved ● Challenges remain ● Significant challenges remain ● Major challenges remain ● Information unavailable

Trends: ↑ On track or maintaining SDG achievement ↗ Moderately improving → Stagnating ↓ Decreasing -- Trend information unavailable

Fig. (10) Egypt's 2021 SDG dashboards, Source: Sustainable Development Report 2021

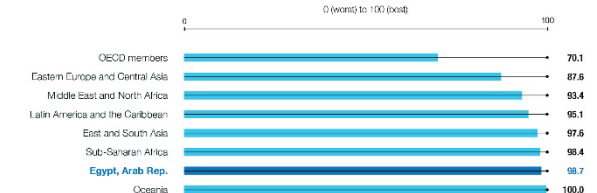
EGYPT, ARAB REPUBLIC OF



SDG DASHBOARDS AND TRENDS



INTERNATIONAL SPILLOVER INDEX



EGYPT, ARAB REPUBLIC OF

Performance by Indicator

| SDG | Indicator | Value | Trend | Target |
|--|--|-----------|-------|------------|
| SDG1 – No Poverty | Poverty headcount ratio at \$1.90/day (%) | 2.4 2021 | ↓ | 3.0 2030 |
| | Poverty headcount ratio at \$5.50/day (%) | 24.8 2021 | ↓ | 3.0 2030 |
| | Proportion of population living in slums (%) | 4.7 2018 | ↓ | 10.0 2030 |
| SDG2 – Zero Hunger | Prevalence of undernourishment (%) | 22.3 2014 | ↓ | 3.0 2030 |
| | Prevalence of stunting in children under 5 years of age (%) | 6.5 2014 | ↓ | 3.0 2030 |
| | Prevalence of obesity, BMI ≥ 30 (%) of adult population | 32.0 2016 | ↓ | 3.0 2030 |
| SDG3 – Good Health and Well-Being | Human Tephrit: mean (per 100,000 population) | 3.2 2017 | ↓ | 3.0 2030 |
| | Gender yield (per hectare of irrigated land) | 7.1 2018 | ↓ | 3.0 2030 |
| | Gender yield (per hectare of irrigated land) | 6.8 2018 | ↓ | 3.0 2030 |
| SDG4 – Quality Education | Net primary enrollment rate (%) | 99.3 2019 | ↑ | 100.0 2030 |
| | Lower secondary completion rate (%) | 88.4 2019 | ↑ | 100.0 2030 |
| | Upper secondary completion rate (%) | 88.2 2017 | ↑ | 100.0 2030 |
| SDG5 – Gender Equality | Ratio of female to male labor force participation rate (%) | 90.0 2014 | ↑ | 100.0 2030 |
| | Ratio of female to male labor force participation rate (%) | 94.9 2019 | ↑ | 100.0 2030 |
| | Ratio of female to male labor force participation rate (%) | 23.9 2019 | ↓ | 100.0 2030 |
| SDG6 – Clean Water and Sanitation | Population using at least basic drinking water services (%) | 96.1 2017 | ↑ | 100.0 2030 |
| | Population using at least basic sanitation services (%) | 94.2 2017 | ↑ | 100.0 2030 |
| | Population using at least basic sanitation services (%) | 1.1 2018 | ↓ | 100.0 2030 |
| SDG7 – Affordable and Clean Energy | Renewable energy consumption (% of total electricity generation) | 42.9 2018 | ↑ | 35.0 2030 |
| | Renewable energy consumption (% of total electricity generation) | 1.8 2019 | ↑ | 35.0 2030 |
| | Renewable energy consumption (% of total electricity generation) | 1.8 2019 | ↑ | 35.0 2030 |
| SDG8 – Decent Work and Economic Growth | Unemployment rate (%) of total labor force | 10.0 2019 | ↓ | 5.0 2030 |
| | Unemployment rate (%) of total labor force | 10.0 2019 | ↓ | 5.0 2030 |
| | Unemployment rate (%) of total labor force | 10.0 2019 | ↓ | 5.0 2030 |
| SDG9 – Industry, Innovation and Infrastructure | Proportion of population using the internet (%) | 57.3 2019 | ↑ | 80.0 2030 |
| | Proportion of population using the internet (%) | 57.3 2019 | ↑ | 80.0 2030 |
| | Proportion of population using the internet (%) | 57.3 2019 | ↑ | 80.0 2030 |
| SDG10 – Reduced Inequalities | Gini coefficient (adjusted for disposable income) | 30.6 2015 | ↓ | 30.0 2030 |
| | Gini coefficient (adjusted for disposable income) | 30.6 2015 | ↓ | 30.0 2030 |
| | Gini coefficient (adjusted for disposable income) | 30.6 2015 | ↓ | 30.0 2030 |
| SDG11 – Sustainable Cities and Communities | Proportion of urban population living in slums (%) | 5.2 2018 | ↓ | 10.0 2030 |
| | Proportion of urban population living in slums (%) | 5.2 2018 | ↓ | 10.0 2030 |
| | Proportion of urban population living in slums (%) | 5.2 2018 | ↓ | 10.0 2030 |
| SDG12 – Responsible Consumption and Production | Electronic waste (kg/capita) | 1.7 2019 | ↓ | 1.0 2030 |
| | Electronic waste (kg/capita) | 1.7 2019 | ↓ | 1.0 2030 |
| | Electronic waste (kg/capita) | 1.7 2019 | ↓ | 1.0 2030 |
| SDG13 – Climate Action | CO2 emissions from fossil fuel combustion and cement production (kt/capita) | 2.5 2019 | ↓ | 1.0 2030 |
| | CO2 emissions from fossil fuel combustion and cement production (kt/capita) | 2.5 2019 | ↓ | 1.0 2030 |
| | CO2 emissions from fossil fuel combustion and cement production (kt/capita) | 2.5 2019 | ↓ | 1.0 2030 |
| SDG14 – Life Below Water | Mean area that is protected in marine areas important to biodiversity (%) | 43.0 2019 | ↓ | 10.0 2030 |
| | Mean area that is protected in marine areas important to biodiversity (%) | 43.0 2019 | ↓ | 10.0 2030 |
| | Mean area that is protected in marine areas important to biodiversity (%) | 43.0 2019 | ↓ | 10.0 2030 |
| SDG15 – Life on Land | Mean area that is protected in terrestrial areas important to biodiversity (%) | 99.7 2019 | ↓ | 10.0 2030 |
| | Mean area that is protected in terrestrial areas important to biodiversity (%) | 99.7 2019 | ↓ | 10.0 2030 |
| | Mean area that is protected in terrestrial areas important to biodiversity (%) | 99.7 2019 | ↓ | 10.0 2030 |
| SDG16 – Peace, Justice and Strong Institutions | Unintentional deaths (per 100,000 population) | 1.6 2019 | ↓ | 1.0 2030 |
| | Unintentional deaths (per 100,000 population) | 1.6 2019 | ↓ | 1.0 2030 |
| | Unintentional deaths (per 100,000 population) | 1.6 2019 | ↓ | 1.0 2030 |
| SDG17 – Partnerships for the Goals | Government spending on health and education (% of GDP) | 5.2 2018 | ↓ | 10.0 2030 |
| | Government spending on health and education (% of GDP) | 5.2 2018 | ↓ | 10.0 2030 |
| | Government spending on health and education (% of GDP) | 5.2 2018 | ↓ | 10.0 2030 |

Fig. (11) Egypt's Decade of Action for the Sustainable Development Goals, Source: Sustainable Development Report

The study suggests the following sustainable development goals to be the most related factors to the purpose of CW project in Egypt and its expected impacts on environment, in relevance to *Africa SDG index and dashboards report 2020, Egypt voluntary national review, 2021 and the SDG index Arab region*.

SDG 6 Clean water and sanitation (Egypt)

- Amount of treated water (m3)
- Anthropogenic wastewater that receives treatment (%)

SDG 11 Sustainable cities and communities (Egypt)

- Per capita green landscapes in cities (m2/capita)
- Annual mean concentration of particulate matter of less than 2.5 microns in diameter (PM2.5)($\mu\text{g}/\text{m}^3$)





















SDG13 – Climate Action

- Energy-related CO2 emissions (tCO2/capita)
- Per Capita CO2 Emissions in Egypt (in metric tons)

2021 Egypt's performance by Indicators

Table (1) Egypt's Performance by Indicator for the concerned SDGs,

Source: Sustainable Development Report 2021, Edited by Author

| | Value | Year | Rating | Trend |
|---|-------|------|---|---|
| SDG6 – Clean Water and Sanitation | | | | |
| Population using at least basic drinking water services (%) | 99.1 | 2017 |  |  |
| Population using at least basic sanitation services (%) | 94.2 | 2017 |  |  |
| Freshwater withdrawal (% of available freshwater resources) | 117.3 | 2017 |  |  |
| Anthropogenic wastewater that receives treatment (%) | 42.0 | 2018 |  |  |
| Scarce water consumption embodied in imports (m3/capita) | 1.6 | 2013 |  |  |
| SDG11 – Sustainable Cities and Communities | | | | |
| Annual mean concentration of particulate matter of less than 2.5 microns in diameter (PM2.5) ($\mu\text{g}/\text{m}^3$) | 91.3 | 2019 |  |  |
| Access to improved water source, piped (% of urban population) | 98.6 | 2017 |  |  |
| SDG13 – Climate Action | | | | |
| CO2 emissions from fossil fuel combustion and cement production (tCO2/capita) | 2.5 | 2019 |  |  |
| CO2 emissions embodied in imports (tCO2/capita) | 0.1 | 2015 |  |  |
| CO2 emissions embodied in fossil fuel exports (kg/capita) | 54.2 | 2019 |  |  |

3.2 Environmental Impact Assessment methods

Aiming to demonstrate the significance of environmental change in a clear consistent way; assessment methods were designed and further developed by many researchers throughout the years. (Martim, H., et al., 2013). For each specific project, the most applicable method should be chosen, therefore people engaged in the environmental impact assessment process should have knowledge about all the assessment methods. (Stamm, H., 2003). The most important environmental impact assessment methods include the ad-hoc method, checklists, interaction networks (Moraes, C. et al., 2016), system diagrams, overlaying charts and matrices (Almeida, S., et al., 2014; Figueiredo, R., et al., 2020).

3.2.1 The Matrices

The simple matrix is basically a set of environmental aspects presented on the vertical axis that is used to verify whether an activity will have a negative impact, no impact or positive impact. A “check mark” is provided in the corresponding column. For assessing various types of projects, different matrices methods have been developed over the years to reach the most suitable assessing method according to each project’s requirements. Leopold Matrix was one of the earliest methods which was first suggested in 1971 (Lohani, B., et al., 1997; Figueiredo, R., et al., 2020). Later in 1974 a different form of matrix was proposed by Environment Canada, to identify the indirect impacts systematically, the method is known as the Component Interaction Matrix. After being recognized all over the world, EIAs started implementing matrices progressively in their impact assessments (Babu S., 2016). Various matrices forms were further developed, including; Modified Graded matrix, Impact Summary matrix, Loran matrix. (Lohani, B., et al., 1997; Elaw, 1998; Babu, S., 2017).

3.2.1.1. Application of matrices

Matrices are effective tools for medium to large scale projects, which normally includes a high number of activities (could reach 100 activity). These activities are expected to have a great impact on various environmental aspects, which is not convenient to be presented in checklists. The matrix is conveniently adapted to the respective project. The number of activities and impacts are variable according to the type of project (Lohani, B., et al., 1997). The flexibility of matrices is one of its main advantages that gives it acceptance and widespread use all over the world as shown in Table (2).

Table (2) Relevant readings and papers, Source: Author

| Author, Date | Method used | Relevant to the Study |
|---|--|---|
| 1- Leopold, L. B. et al. (1971) 2- Pone, V.M. (1999-2021) 3- FAO (1996) 4- Muslem M. et al. (2010) 5- Figueiredo, R., et al. (2020) | Leopold Matrix | 100 indicators, some of which can be applied to constructed wetland parks |
| Al-Nasrawi F. A. et al. (2020) | Leopold Matrix | Assess the Environmental Impact of Pollution from fresh Water Projects in Iraq |
| Josimović, B., et al. (2014) | Leopold Matrix | Carrying Out the EIA |
| Lohani, B., J.W et al. (1997) | Matrices in Environmental Impact Assessment | Matrices and other tools for EIA |
| 1- Lohani, B. (2017) 2- Elaw (1998) 3- Babu s. (2017) | Methods of investigating impacts; Modifications of matrices | Modifications of matrices: 1- Leopold Matrix 2- Modified Graded Matrix 3- Impact Summary Matrix 4- Loran Matrix |
| Bowd, R., et al. (2015) | 1- Leopold Matrix 2- The Peterson Matrix (Peterson et al. 1974) | Limitations of the Leopold Matrix |
| Müller, N. et al. (2016) | URBO Index | Using URBO Index to evaluate parks under all aspects of sustainability |
| Zakaria, Y., et. al. (2021) | The Rapid Sustainability Screening (RSS) model | Sustainability Assessment of wastewater treatment systems (WWTS), both planned and existing |

3.2.1.2. Leopold matrix

In 1971 and in response to the U.S. Environmental Policy Act of 1969, which did not offer strong guidelines for preparing an environmental impact report for a project, Geologist Luna Bergere Leopold and colleagues created the Leopold's Matrix. (Josimović, B., et al., 2014) (Figueiredo, R., et al., 2020). The proposed matrix is one of the two main forms of matrices used in EIA, providing an easy way for summarizing and classifying the environmental impacts and focusing on the greatest ones (Ponce, V., 2009). It also provides a complete overview of the project activities, the resulting impacts and the affected environmental conditions, so that the most affecting actions and the most affected environmental conditions can be ascertained. (Econservation, 2017; Figueiredo, R., et al., 2020). Nevertheless, it provides a structure for analyzing and weighting potential impacts numerically. The analysis lacks providing an overall quantitative assessment; Rather, it depicts many value evaluations. The main objective is ensuring that the impacts of different activities are assessed and taken into account when planning a project. (Ponce, V., 2009)

As a qualitative measure of the environmental/social impact of a project, the Leopold Matrix provides an overall structure for a broad evaluation of the interactions amongst anticipated human activities and environmental aspects. On the horizontal axis, a list of 100 project actions representing the measures causing an environmental impact. About 88 environmental / social aspects are listed on the vertical axis representing the current environmental aspects and impacts that can be affected by each of the project activities on the horizontal axis. With a total of 8800 interactions offered. (Lohani, B., et al., 1997) (Ponce, V., 2009)

Virtually, it is likely that few interactions will have impacts of that magnitude and importance to deserve comprehensive treatment. Overall, only about twelve actions will be of interest, since not all of these activities and actions are necessarily applicable to all projects; Whereas, in some cases, the presence of other activities and factors, that is not considered in Leopold matrix, may be justified (Ponce, V., 2009). Generally, it is expected that most projects' interactions are within the average of 25 to 50 (Leopold, L. B. et al, 1971; Figueiredo, R., et al., 2020). A sample of a Leopold matrix is shown in Fig. (12), presenting a model of five activities with impacts on four environmental aspects, where blank cells indicates that the activity does not have impact on the environmental aspect.

| | | Project Activities of Impacts | | | | |
|-----------------------|----------|-------------------------------|------------|------------|------------|------------|
| | | Activity 1 | Activity 2 | Activity 3 | Activity 4 | Activity 5 |
| | | | | | | |
| Environmental Aspects | Aspect 1 | 2 1 | 1 4 | | 8 6 | 2 1 |
| | Aspect 2 | | 10 5 | 2 1 | 3 4 | |
| | Aspect 3 | | | | 1 4 | 3 3 |
| | Aspect 4 | 1 1 | 2 2 | | | |

Fig. (12) Leopold matrix sample, Source: Author from Figueiredo, R., et al., 2020

The assessor is required to quantify his own assessment of the possible impacts of the rating system. The system enables reviewers to methodically understand the logic of the assessor, to identify matches and inconsistencies. Which makes the matrix indeed a summary of the EIA text (Ponce, V., 2009)

3.2.1.3. Leopold matrix Methodology

For efficient use of the matrix, it is required to review each action of significance on the horizontal axis and evaluate it in relation to the magnitude of impact on the environmental aspect on the vertical axis. A diagonal line is dividing the matrix cells from top right to bottom left, where the impact's magnitude of the activity on the environmental aspect is described in the upper section. The lower section describes the impact's significance. (Ponce, V., 2009; Babu, S., 2016; Al-Nasrawi, F. et al., 2020) The text discussion must clearly indicate whether the evaluation is short-term or long-term impact. (Ponce, V., 2009)

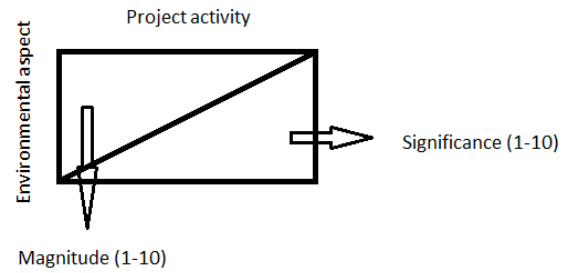


Fig. (13) Leopold matrix Cell, Source: Babu, S., 2016

Each cell is individually evaluated, where the magnitude and significance are subjective for the evaluator, based on the collected basic data and are rated on a scale from 1 to 10 (1 indicating the least and 10 for the largest degree of impact on the specific environmental aspect). The assigned values are based, as far as possible, on facts and not on the preference of the evaluator. Non-divided cell indicates that the activity does not impact the environmental aspect (Leopold, L. B. et al, 1971; Lohani, B., et al., 1997; Ponce, V., 2009; Babu, S., 2016; FAO, 1996; Al-Nasrawi, F. et al., 2020). Values can be positive, indicating that the impact is beneficial, or negative, indicating that the impact is harmful. (Figueiredo, R., et al., 2020)

After assessment of the given values in the cells, it is useful to identify the highly interactive actions and environmental aspects and create a shortened (reduced) matrix that include only those identified. Cells with large numbers can be given special attention. (Ponce, V., 2009)

3.2.1.4. Advantages of Leopold matrix

The advantage of matrix formatting is including a full range of related actions, factors, and impacts. The magnitude is to a large extent assigned on the basis of factual information. As for the importance, assignment can, however, give an opportunity for the subjective view of the practitioner. An important advantage of Leopold matrix is this distinction between facts and views. (Ponce, V., 2009)

On the other hand, it has been recognized over time that in many cases two criteria are not sufficient for an effective EIA. Some researchers attempted to create a framework for creating a new, more complete matrix derived from Leopold. According to researchers' reviews, it is clear that each author chose to create his own matrix without any consistency, which led to the lack of analysis of some parameters and relevant information, the difficulty of its formation, and other disadvantages. (Figueiredo, R., et al., 2020)

3.2.1.5. Disadvantages of Leopold matrix

Not explicitly describing the spatio-temporal effects of environmental activity is considered the main drawback of the Leopold matrix. It simply provides the interaction's magnitude and significance. Another drawback is that it is considered oversimplified when a full impact analysis on the project area is required; the magnitude and impact's numerical value are insufficient for the contractor's understanding of the activities' impact and the intentions to overcome it. Another disadvantage is the inability to explain the relationship between two environmental aspects. That is, the inability to define the secondary and tertiary impacts. The possibility of having multiple levels of impacts on the environmental aspects from more than one activity. Gathering this information would be very hard. (Lohani, B., et al., 1997)

On the other hand, the Leopold matrix has limitations when applied to the complex socio-economic aspects. (Bowd, R., et al., 2015). Apart from the difficulties in carrying out qualitative assessments of socio-economic impact (Barrow, C., 1997); Scoring raises subjective questions that require higher knowledge requirements (Glasson, J. et al., 2005, Kassim, T. et al., 2005). Accommodating both qualitative and quantitative data without clearly distinguishing between them (Munn, R., 1979; Kassim, T. et al., 2005). The accuracy of the tools is restricted by the adequacy of the available data and the practitioner knowledge level (Glasson, J. et al., 2005).

It also accommodates quantification of the impacts and their significance, as it identifies the impacts, but it does not specify the significance, magnitude, or extent of the change (Barrow, C., 1997). The details of the methodology / technology used to predict impacts are not incorporated in the matrix approaches (Glasson, J. et al., 2005). Dealing equally with uncertainty and the impacts probabilities, treating all expectations as if they would certainly occur (Kassim, T. et al., 2005). While matrix approaches are incapable of distinguishing significant indirect, secondary or cumulative impacts, they adopt indirect, temporary and long-term impacts (Bowd, R., et al., 2015). Thus, lacking a clear distinction between the current and future state of the system, Since the results are summarized in a single diagram, interactions can occur (Kassim, T. et al., 2005).

3.2.1.6. Leopold Matrix for Environmental Impact Assessment

A successful EIA's core usually relies on a comprehensive management of project's challenges, their impacts on valuable factors, and a clear mitigation proposal actions that efficiently reduce these impacts. The methodology of providing this information regarding the different project's phases: initial design, final design, construction and operation. This approach relates element impacts to the phase(s) of the project in which they are generated. Tackling the impact over the linked project phase clearly suggests which project's aspects need mitigation actions through design modifications and alignment of mitigation decisions with the project implementation schedule. (Lohani, B., et al., 1997)

Impacts during the construction phase: The construction phase generally comprises environmental impacts that end after construction completion. Impacts could be significant, particularly if the construction period extends over several years. The EIA should clearly discuss the impacts and the suggested mitigation actions for reduction or prevention of those impacts. (Lohani, B., et al., 1997)

Impacts during the Operation phase: Description of project's impacts reduction through mitigation actions during the project's development and operation phases is a key purpose of an environmental assessment. Since environmental assessments typically take place early in the project development phases when many project design and operational details are uncertain, mitigation options for potential impacts often cannot be described within the required confidence levels. (Lohani, B., et al., 1997)

CWP system Lifetime: As previously discussed in chapter 2, constructed wetland projects for wastewater treatment can have a limited lifespan determined by sewage contamination, the wetland's ability to remove and store pollutants, and the accumulation of waste. Several CW systems have been in operation for more than 20 years with minor or no loss of efficiency. As more CW systems are observed over greater intervals of time, long-term records on the performance of constructed wetlands are developed. (Davis, L., 1995)

For a precise and accurate assessment of park performance, a specific designed metrics is best to be tailored for each park according to the different circumstances and characteristics of each park.

The Environmental Impact Assessment (EIA) through the Leopold Matrix is simply an analysis of the cells with larger numbers of Magnitude and Significance. Columns with many factors are discussed in detail regardless of the assigned numbers. Similarly, Rows with many actions are also discussed in detail, regardless of the assigned number. (Ponce, V., 2009)

The analysis discussion covers diverse points or aspects starting with the description of the proposed action and the probable impact of the proposed action on the individual factor. It also discusses any adverse environmental effects which cannot be avoided and alternatives to the proposed action. The relation between local short-term use of the human environment and the maintenance and enhancement of long-term productivity could also be discussed. Nevertheless, any irreversible and irretrievable commitments of resources which would be involved in the proposed action and any other issues raised by federal, state, and local agencies, and by appropriate organizations or individuals. (Ponce, V., 2009)

The EIA text is a discussion of the explanations for associating the score values of the impact's magnitude and significance. A symposium of the key features of the suggested action and including the involved ecosystem. The EIA also includes the physics, chemistry and biology descriptive facts of the suggested action and the ecosystem involved. The level of detail should only be what is required for an EIA. (Ponce, V., 2009)

This study aims to reach a new assessment tool, Leopold-derived matrix, that is better adapted to the actions and activities of Constructed Wetland Parks, in relation to convenient environmental aspects. Adding a range of suggested information and tools to aid in the assessment for each criterion, leading to an appropriate environmental impacts assessment work and providing practitioners with a coherent simple collection of information and variant tools for assessment and hence, for decision making.

3.2.1.7. Leopold Matrix Adaptation

In general, Leopold Matrix is quite generic, yet the matrices can be adapted to fit the evaluated project's needs. It is preferable that the matrices include both the construction and operational phases of the project as the first sometimes has a significant impact than the second. (Lohani, B., et al., 1997).

In a research study for assessing the environmental impact assessment of Wind Farms in Serbia using the Leopold Matrix, a suggestion was concluded about using new criteria in addition to the standard model of the Leopold matrix. These new criteria are; Impact significance, Impact probability and Impact duration. (Josimović, B., et al., 2014) Each was assessed on a separate matrix with a single score represented on the cells. Each impact factor was assessed separately for every environmental aspect relevant to the study.

Impact factors have been evaluated separately for each environmental component relevant for the scope of the study. Additionally, physical, biological and socio-cultural environmental aspects was separated, and 16 environmental aspects was defined. Evaluation for the impact factors for the environmental aspects was performed. The results were presented in 4 separate tables for all environmental aspects and impact factors in the structure of Leopold matrix, and later elaborated in a suitable way. (Josimović, B., et al., 2014)

In another research study for assessing the Environmental Impact of Pollution from Drinking Water Projects in Iraq using the Leopold Matrix. Some equations were suggested to calculate the Impact's Magnitude. The Impact's Significance Evaluation was based on judgement of relevant fields experts. Some adjustments were applied on the Leopold matrix to best fit the project's requirements through adding the calculation of each pollutant's impact value on the environment, the total environmental impact value and the ratio of impact pollutant from total. (Al-Nasrawi, F. et al., 2020)

Despite the simple factual assessment of the Impact's Magnitude, the assessment of the Impact's Significance is generally based on the assessor's value evaluation. (Leopold, L. B. et al, 1971). The Environmental Impact's Significance should consider the consequences of altering a particular condition for other environmental factors (Leopold, L. B. et al, 1971). The Impact's significance scale ranges from 1 (very little interaction) to 10 (significant interaction) (FAO, 1996; Al-Nasrawi, F. et al., 2020)

The following equations could be used, when relevant, to determine the magnitude of impact. Where the first equation (Eq. 5) is relevant whenever there are existing standards for the element, while the second equation (Eq. 6) is more relevant whenever there are no existing standards. (Muslem M. et al, 2010; Al-Nasrawi, F. et al., 2020)

$$\text{Magnitude (M)} = \frac{\text{Pollutant concentration (in working state)}}{\text{Standard limits (concentration)}} \quad \text{Equation (1)}$$

$$\text{Magnitude (M)} = \frac{\text{Pollutant concentration (in working state)}}{\text{Element concentration (in design state)}} \quad \text{Equation (2)}$$

3.2.2 URBIO Index

The URBIO Index is an evaluation tool for the sustainable design of green spaces that was Suggested by Norbert Müller, during a workshop in Fachhochschule Erfurt in 2016. The URBIO Index is a tool designed to support landscape architects, restoration ecologists, and urban planners and designers in their attempts for designing a green sustainable infrastructure. It supports the assessments of parks according to all aspects of sustainability through 25 indicators. Müller has developed the URBIO Index as an assessment tool for evaluating the sustainability of green spaces (Müller, N. et al. 2016).

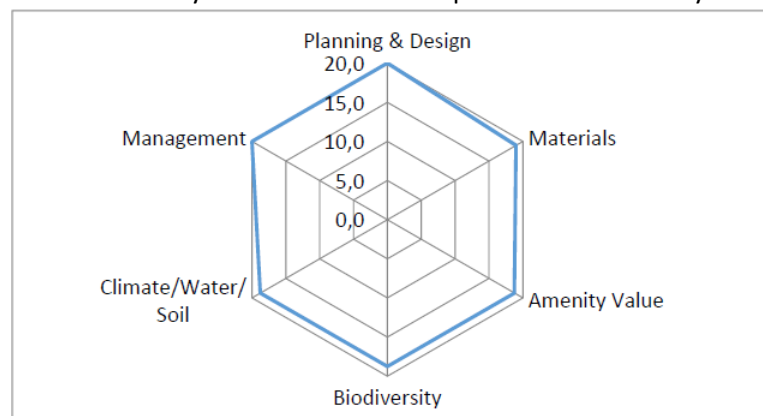
The proposed index is evaluating the project through the assessment of the comprised six thematically indicator groups with total of 25 indicators. Each of the Indicator themes are presented on a separate sheet and a collective sheet is presenting the overall assessment. (Müller, N. et al. 2016).

| Indicators | | Sustainability goals |
|-------------------------------|--|--|
| Planning | | |
| 1 | Planning and design | Satisfaction of user |
| 2 | Sustainability as a planning target | Sustainable outdoor quality |
| 3 | Citizen / user participation during the planning | Wide acceptance and user satisfaction |
| 4 | Comparison previous use | Improvement of site quality |
| Materials | | |
| 5 | Use of autochthonous plant materials - trees and shrubs | Conservation and support biodiversity |
| 6 | Use of autochthonous plant materials – herbs and grasses | Conservation and support biodiversity |
| 7 | Selection of materials | Care of resources |
| 8 | Use of certified timber | Support sustainable forestry |
| 9 | Recyclability of materials | Care of resources |
| Amenity / Value | | |
| 10 | Barrier-free (for handicapped) | User comfort |
| 11 | Accessibility for the public | Save energy |
| 12 | Diverse usage possibilities | User comfort |
| 13 | User friendliness | User comfort |
| Biodiversity | | |
| 14 | Diversity of habitats | Support biodiversity |
| 15 | Presence of key-species | Support biodiversity |
| 16 | Habitat connectivity | Support biodiversity |
| 17 | Space for succession | Support biodiversity |
| Climate / Water / Soil | | |
| 18 | Climate | Climate change mitigation / adaptation |
| 19 | Groundwater | Groundwater protection |
| 20 | Percentage sealed surfaces | Soil conservation |
| 21 | Soil conservation measures (during the work stage) | Soil conservation |
| Management | | |
| 22 | Site specific plant use | Minimize maintenance |
| 23 | Use of rainwater | Sustainable use of water |
| 24 | Illumination | Energy efficiency and light pollution |
| 25 | Maintenance concept | Sustainable management |

Table (3) URBIO Index indicators and goals, Source: Müller, N. et al. 2016 edited by Author

The application of the assessments includes different assessment sequences. Starting with the examination and analysis of the park as a first stage, which includes a brief photo documentation. The park's stakeholders (owners, users and/or planners) are then consulted. Lastly, the design and construction documentation are analyzed. The Park is then assessed, according to this analysis, on the basis of the 25 indicators. A maximum of 4 points can be allocated to each indicator, with a maximum achievement of 100 points. The testing phase showed that, unlike other systems, the URBIO Index is easy to use and covers important sustainability criteria (Müller, N. et al. 2016).

Fig. (14) URBIO Index outcome,
Source: Müller, N. et al. 2016



3.3 Suggested Main Indicators of sustainability:

This study presents and demonstrates a proposed spatial framework for the application of environmental impact assessment in the context of assessing constructed wetland parks in the urban wetland environments. The proposed framework is focused on the main 3 pillars of sustainability: Environmental, Social and Economic. The Environmental aspect is then categorized into four main categories that are the main critical environmental factors that can describe the influence of the parks to the adjacent Urban. The four aspects are Climatic, Sustainability, Biodiversity and Water, each is then divided into sub-categories that evaluate the performance in quantitative descriptive way.

Indicators for sustainable landscape have been studied by several researchers to understand the main factors contributing to achieving the landscape sustainability. (Çiftçioğlu, G., et al., 2015)

Existing tools in landscape architecture are not reflecting all sustainability aspects and due to their complexity and difficulties in implementation, this study is aiming to propose an assessment tool that includes all aspects of sustainability, and that is affordable and unexpensive, to assist landscape architects and small local project in improving sustainability and saving the environment all over the world, especially in developing countries. The included sustainability aspects cover the 3 main pillars and give attention to:

- a) **Environmental aspects:** Ecological preservation and development of biodiversity through local and indigenous plants and the improvement of climate mitigation and air quality
- b) **Social aspects:** Involvement of users and residents in the design and management of public green spaces
- c) **Economical aspects:** Improvement of local economy, waste treatment and the use of local materials

3.3.1 Indicator's selection criteria and categorization:

The suggested method for CW parks assessment proposed some sustainability indicators for assessment. The selection was focusing on relating those proposed indicators to various indicators from the UN global SDGs, national SDGs, in addition to indicators directly related to the functionality of CWs.

The indicators chosen should be relevant and reflect the process for which they are intended for their evaluation. The indicators should also be sensitive to changes over time, easy to measure and feasible at all levels; Effort, time and skills required and is easy to interpret and understand to a variety of end-users and stakeholders.

In order to propose an effective easy to use CW Parks sustainability matrix, the research followed systematic methods. The first step was identifying and selecting the indicators and categorizing them according to main sustainability pillars. Adopting the Leopold matrix method, the convenient activities and environmental aspects were listed in a matrix. Later the sustainable indicators were subcategorized and classified in respect to the project's phases.

The method adopted focus on classifying indicators into criteria and sub criteria. Hence, the impact factors would be evaluated separately for each relevant environmental component and scored on a scale from 0 to 5 for Impact Magnitude. In addition to the standard form of the Leopold matrix, the new criteria have also been used; Significance, Probability and Duration.

3.3.2 Adapted Leopold matrix application on CW Parks indicators

The proposed CW Parks sustainability matrix adopted the Leopold matrix method where the convenient activities for the CW Parks were added on the horizontal axis and the proposed environmental aspect were added to the vertical axis.

Table (4) Suggested activities in Leopold Matrix for CW Parks Assessment on Horizontal axis, Source: Author

| A. Modification of regime | | | | | | | | B. Land transformation & construction | | D. Processing | E. Land alteration | | F. Resource renewal | | | | H. Waste emplacement and treatment | | | | I. Chemical treatment | | K. Others | | | | |
|------------------------------------|---------------------|-------------------------|----------------------------|------------------------|----------------------|-------------------|---------------------|---------------------------------------|-------------------------|-------------------|-------------------------------|-------------|---------------------|----------------------------------|----------------------|---------------------------|------------------------------------|---------------------------|---------------------------|-----------------------------------|-------------------------------------|----------------------------|------------------|---------------|---------------------------------|------------------|------------------|
| Exotic flora or fauna introduction | Biological controls | Modification of habitat | Alteration of ground cover | Alteration of drainage | Weather modification | Surface or paving | Noise and vibration | Urbanization | Recreational structures | Energy generation | Erosion control and terracing | Landscaping | Reforestation | Wildlife stocking and management | Groundwater recharge | Fertilization application | Waste recycling | Municipal waste discharge | Liquid effluent discharge | Stabilization and oxidation ponds | Septic tanks, commercial & domestic | Stack and exhaust emission | Spent lubricants | Fertilization | Chemical stabilization of soils | To be determined | To be determined |

Table (5) Suggested environmental aspect in Leopold Matrix for CW Parks Assessment on Vertical axis, Source: Author

| | | |
|--|---------------------------------------|--|
| A. Physical and chemical characteristics | 1. Earth | c. Soils |
| | 2. Water | d. Quality f. Recharge |
| | 3. Atmosphere | a. Quality (gases, particulates) b. Climate (micro, macro) c. Temperature |
| B. Biological conditions | 1. Flora | a. Trees b. Shrubs c. Grass d. Crops e. Microflora f. Aquatic plants h. Barriers i. Corridors |
| | | a. Birds b. Land animals, including reptiles d. Benthic organisms e. Insects f. Microfauna h. Barriers i. Corridors |
| | 2. Fauna | a. Wilderness and open spaces b. Wetlands f. Picnicking |
| | | a. Scenic view and vistas b. Wilderness qualities c. Open space qualities d. Landscape design e. Unique physical features f. Parks and reserves |
| | | a. Cultural patterns (life style) b. Health and safety c. Employment d. Population density |
| | | a. Structures c. Utility networks d. Waste disposal |
| | 5. Man-made facilities and activities | a. Salinization of water resources g. Other |
| | | a. To be determined b. To be determined |
| C. Cultural factors | 1. Land use | a. Wilderness and open spaces b. Wetlands f. Picnicking |
| | 2. Recreation | a. Scenic view and vistas b. Wilderness qualities c. Open space qualities d. Landscape design e. Unique physical features f. Parks and reserves |
| | 3. Aesthetics and human interest | a. Cultural patterns (life style) b. Health and safety c. Employment d. Population density |
| | 4. Cultural status | a. Structures c. Utility networks d. Waste disposal |
| | 5. Man-made facilities and activities | a. Salinization of water resources g. Other |
| | D. Ecological relationships | a. To be determined b. To be determined |
| | | a. To be determined b. To be determined |
| | E. Others | a. To be determined b. To be determined |
| | | a. To be determined b. To be determined |
| | D. Ecological relationships | a. Salinization of water resources g. Other |
| | | a. To be determined b. To be determined |

3.3.3 Categorizing and classifying sustainable indicators for CW parks:

This step included subcategorizing the selected Environmental indicators to the main environmental aspects; Climatic, Sustainability, Biodiversity and Water aspects. Each was then categorized to specific measurable factors. To address the limitations in the Leopold matrix, the Social Impact Factors and the Economical-Technical Factors were also added to the matrix, and each was subcategorized with specific detailed factors. The adapted Leopold matrix for CW Parks sustainability indicators depends on linking proposed indicators to the major two phases in the life cycle of the CW Parks: Construction and Operation Phases. (Lohani, B., et al., 1997) While the third phase “Demolition Phase” was excluded due to its minor effect as it is believed not to include any specific major activities except of backfilling the water path. (Davis, L., 1995)

3.3.3.1 Adopted environmental indicators

A set of indicators are selected for measuring wetland impact and sustainability. The indicators were categorized to 4 main aspects according to the type of influence on the environment as follows:

1- Climatic Aspects

- Air Quality
- Urban Micro-Climate
- Carbon Footprint

2- Sustainability

- Energy
- Materials
- Solid/Liquid Wastes
- Soil

3- Biodiversity; Flora & Fauna Habitat Diversity

- Flora (Vegetation)
- Fauna

4- Water:

- Water Reused
- Water Quality

3.3.3.2 Adopted Socio-Cultural indicators

1- Community Values

- Community Size Served
- Community Awareness
- Community Acceptance

2- Social Values

- Education / Training
- Public Participation
- Increased Recreational & Social Activities
- Added Social & Connectivity Values

3- Aesthetic Values

- Visual Aesthetic Value
- Odor Reduction Efficiency

3.3.3.3 Adopted Economical -Technical indicators

1- Economic Values

- Catalyzing Economic Development
- Land Use Value
- Economic Savings
- Potentials of Economic Revenue

2- Technical Values

- Construction Process Flexibility
- Operation & Maintenance Process Flexibility
- Future Potential for Upgrading

3.3.4 Validation methodology and Criteria weighting:

For validating the results of the proposed indicators categories, a quantitative analysis is required. The analysis is based on a structured questionnaire evaluating the validity and relevance of the selected indicators; a vital process in assessing CW Parks in terms of sustainability. The indicators' relative importance is determined by the assignment of weights. These weights are extremely important as they demonstrate their contribution to the sustainable performance of CW parks. Weights are also used to determine whether various indicators are substituting or compensating for each other.

In general, methods of weighting are divided into 3 main categories; equal weighting methods, statistics-based methods and expert / public opinion-based methods (Gan, X., et al. 2017). Equal weighting is an uncomplicated option, suggesting that all indicators are similarly important with non-supporting statistical or empirical data for other options. Yet, it is very well doubtful in terms of clarity and validity of the results. On the other hand, to assess the relationships between the indicators instead of weighting them, Statistics-based methods are primarily used, such as factor analysis. While, Expert opinion methods are based on extensive knowledge, such as the Budget allocation method (BAL), in which indicator's higher points "n" represent a higher budget allocation. This method is direct and not just transparent, which is its main advantage. Even though, it could be criticized because sometimes it may be weighted according to public and political concerns rather than the actual contribution of indicators to sustainability. Public opinion weighting methods is depending on stakeholders' interests about different dimensions of sustainability. It has a straightforward character and its implementation is short and simple. Results are more local and not convenient to various sites, which is its main drawback. (Kourtzanidis, K., 2021; Pakzad, P. et al., 2017).

In this study, the weights of the major assessment categories are determined using BAL, and the individual indicators' weights are determined using public opinion method.

3.3.5 Questionnaire design:

The questionnaire design was based on a series of open-ended, closed-ended questions and the use of a 5-point Likert scale. It comprises 4 hierarchical sections, each of which has a specific purpose.

First Section: Participant's Profile: Comprises 3 questions designed to identify the participants' background, area of expertise and nationality to ensure participation from all over the world.

Second Section: Determination of the weights for the main categories of CW Parks sustainability assessment: Here the BAL method is used, in which each participant distributes 10 points over the three indicator categories (Environment, Social-Cultural as well as Economic-Technical). Then the importance of each category is determined from a mean value calculated from the averaged full results.

Third Section: Individual Indicator Weights identification: Participants rate each Indicator's importance in achieving sustainability using a 5-point Likert scale component, with 1 indicating least important and 5 indicating most important. A weighted average (WAI) is used to determine these values. For this index, the weighted score values vary between 0.2 and 1 and are multiplied by the number of respondents involved, then the result score is divided by the total respondents' number, as shown in the following equation (Pakzad, P. et al., 2017):

$$WAI = \frac{\sum f_i w_i}{\sum f_i}$$

Where: f_i = frequency of respective respondents

w_i = weight of each score value:

1 (not important) = 0.2

2 (slightly important) = 0.4

3 (moderately important) = 0.6

4 (Important) = 0.8

5 (very important) = 1

Please note that:

1. The Questionnaire's questions and format are shown in appendix (1)
2. The analysis of each question results is shown in appendix (2)
3. Questionnaire's Link: https://docs.google.com/forms/d/e/1FAIpQLSdaP-IS58thF4shtn2YKnKdeZnmDpf3CCUP6NiYH3A6Q5uICQ/viewform?usp=sf_link

3.3.6 Questionnaire analysis and Weights result

A questionnaire was created in collaboration with an academic group, (Rasha Gaber, Walaa ElSayed, Hind Mostafa), and will be published as a scientific paper. The suggested impacts were discussed and developed by the team, and the former, Gaber, R., translated the impacts into questionnaire's questions and designed the google form, the latter shared the questionnaire on professional groups on Facebook while the author shared it amongst international professionals via WhatsApp, Facebook and email. The author then concluded the results through the following questionnaire analysis and weights calculations, those weights will be used in the author's proposed assessment tool in chapter 5. The questionnaire was aiming to target different professionals of diverse backgrounds and cultures and of different areas of interests in constructed wetland projects. The analysis of the questionnaire participants showed that this aim has been reached and showed the participation of professionals from all over the world with diverse backgrounds and areas of focus.

3.3.6.1. Personal Profile Questions:

Q1_ Please identify your professional sector(s)

| Q1_Professional Sector | Quantity | Percent |
|---|------------|-------------|
| Architecture / Landscape / urban planning | 58 | 43.28% |
| Civil / Infrastructure engineering | 4 | 2.99% |
| Project Management | 5 | 3.73% |
| Agriculture | 5 | 3.73% |
| Academic staff and researchers | 50 | 37.31% |
| Local municipality | 1 | 0.75% |
| Real-estate development | 2 | 1.49% |
| Other | 6 | 4.48% |
| Preferred not to Mention | 3 | 2.24% |
| Total | 134 | 100% |

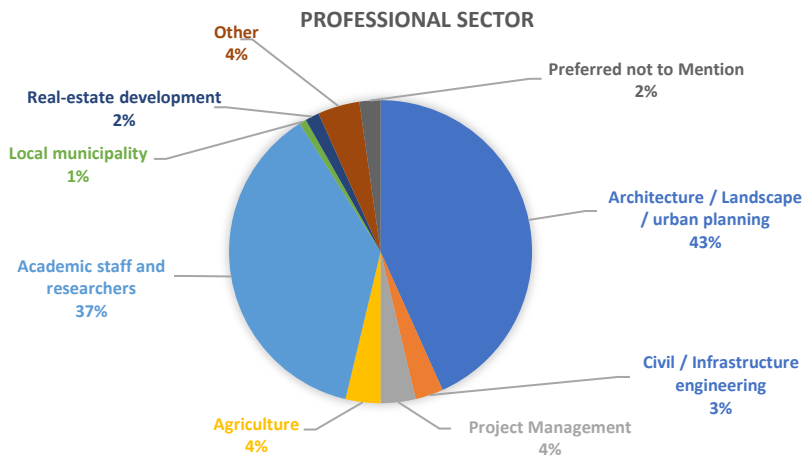


Fig. (15) Questionnaire Analysis, Question 1, Source: Author

43% of the respondents were professionals in **Architecture, Landscape and Urban planning** fields, 37% were **academic staff or researchers**, and almost quarter of the participants were from various other professional sectors, representing most of the related sectors of constructed wetland projects, while some are professionals in more than one sector. These divers' answers from various professional fields would give some good understanding of the impacts weight according to different perceptions of concerned professional sectors.

Q2_ Please identify the main area (s) of focus in your work? (Select all applicable areas)

| Q2_Area of Focus | Quantity | Percent |
|--|------------|-------------|
| Biodiversity Enhancement | 13 | 5.22% |
| Climate change mitigation | 28 | 11.24% |
| Ecology | 18 | 7.23% |
| Energy Conservation | 18 | 7.23% |
| Green & blue Infrastructure / Nature-based solutions | 33 | 13.25% |
| Human wellbeing/Quality of life | 29 | 11.65% |
| Landscape / Agronomy | 42 | 16.87% |
| Pollution / Air quality | 17 | 6.83% |
| Resource (Materials) management | 11 | 4.42% |
| Water quality | 26 | 10.44% |
| Other | 7 | 2.81% |
| Preferred not to Mention | 7 | 2.81% |
| Total | 249 | 100% |

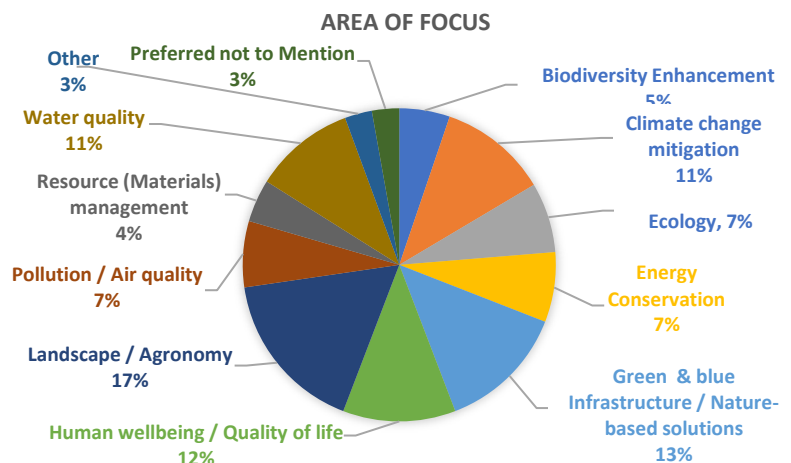


Fig. (16) Questionnaire Analysis, Question 2, Source: Author

17% on average of the respondents were with interest and focus on **Landscape and Agronomy** sectors, average of 13% with area of focus on **Green & blue Infrastructure / Nature-based solutions**, 12% were focusing more on **Human wellbeing & Quality of life**, 11% were focusing more on **Climate change mitigation**, and **Water quality**, and around 7% were also interested in **Ecology** and **Energy Conservation** and **Pollution & Air quality**. 5% focus on **Biodiversity Enhancement**, 4% on Resource management. These diversity in focus area and fields on interest would also give some good insight and understanding of the impacts weight according to different perceptions of concerned interest fields.

Q3_Nationality

| Q3_Nationality | Quantity | Percent |
|--------------------------|------------|-------------|
| Egyptian | 35 | 33.65% |
| German | 3 | 2.88% |
| Jordanian | 2 | 1.92% |
| Austrian | 1 | 0.96% |
| Syrian | 1 | 0.96% |
| USA | 2 | 1.92% |
| Thai | 1 | 0.96% |
| Mexican | 1 | 0.96% |
| Uruguayan | 1 | 0.96% |
| Nepalese | 1 | 0.96% |
| Korea | 1 | 0.96% |
| Malaysian | 1 | 0.96% |
| Serbian | 2 | 1.92% |
| Colombia | 1 | 0.96% |
| Romania | 1 | 0.96% |
| Chinese | 2 | 1.92% |
| Honduran | 1 | 0.96% |
| Other | 9 | 8.65% |
| Preferred not to Mention | 38 | 36.54% |
| Total | 104 | 100% |

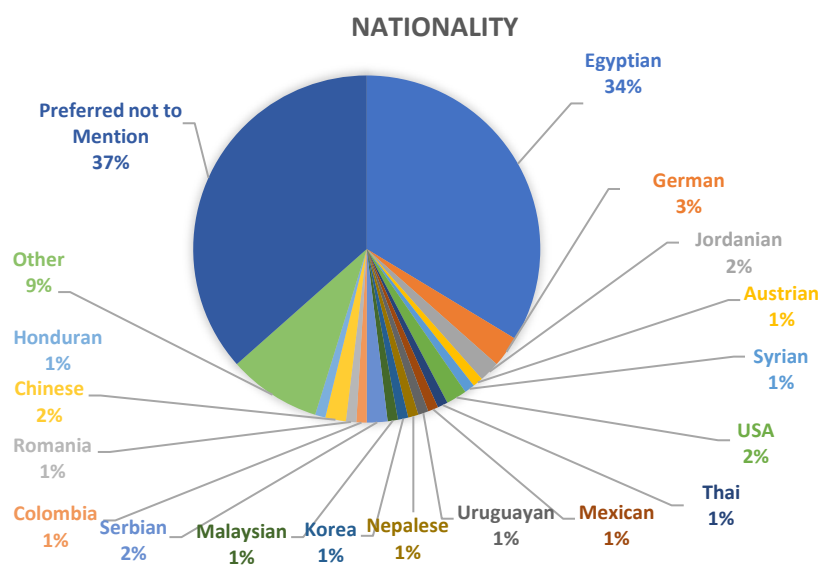


Fig. (17) Questionnaire Analysis, Question 3, Source: Author

34% of the respondents were from **Egypt**, 3% were **Germans**, and other participations from **16 different countries**, 9% were from **other** non-mentioned countries, and **37%** preferred not to mention their country. These divers' answers from different countries would give some good understanding of the perception of impact weight from different countries with diverse environmental, social, cultural, economic and technical values and backgrounds, which can give the weights more indicative value globally.

3.3.6.2. Weight calculation Questions:

Objective 1- Determination of weights for the main categories of CW Parks sustainability assessment

Weighting assessment of main sustainability categories of constructed wetland parks, according to the equation:

$$WAI = \frac{\sum f_i w_i}{\sum f_i}$$

Where: f_i = frequency of respective respondents

w_i = weight of each score value:

1 (not important) = 0.1

.... increasing 0.1 for each point

5 (moderately important) = 0.5

.... increasing 0.1 for each point

10 (very important) = 1

For example, calculations for Environmental Impact weight

| Q4_Environmental Impacts (0-10) points | Respondents | Score Weight | Percent |
|--|-------------|--------------|-------------|
| 1 out of 10 | 1 | 0.1 | 0.96% |
| 2 out of 10 | 4 | 0.2 | 3.85% |
| 3 out of 10 | 21 | 0.3 | 20.19% |
| 4 out of 10 | 29 | 0.4 | 27.88% |
| 5 out of 10 | 29 | 0.5 | 27.88% |
| 6 out of 10 | 8 | 0.6 | 7.69% |
| 7 out of 10 | 1 | 0.7 | 0.96% |
| 8 out of 10 | 0 | 0.8 | 0 % |
| 9 out of 10 | 0 | 0.9 | 0 % |
| 10 out of 10 | 1 | 0.9 | 0.01 |
| 0 out of 10 | 0 | 1 | 0.96% |
| Equal | 7 | | 6.73% |
| Preferred not to mention | 3 | | 2.88% |
| Total | 104 | | 100% |

$$WAI = \frac{\sum \# \text{ Respondents} * \text{Score Weight}}{\sum \# \text{ Respondents}} =$$

$$= \frac{(1*0.1)+(4*0.2)+(21*0.3)+(29*0.4)+(29*0.5)+(8*0.6)+(1*0.7)+(0*0.8)+(0*0.9)+(1*0.9)+(0*1)}{(104-10)}$$

$$= \frac{39.8}{94} = 0.4234$$

∴ WAI of Environmental Impact = 0.4234

Fig. (18) Questionnaire Analysis, Question 4 example for category's weight calculations, Source: Author

Weights for the main categories of CW Parks sustainability

| Sustainability Pillars' Weights | WAI Impact Weight | Percent from Total | Impacts Sustainability Score |
|---------------------------------|-------------------|--------------------|------------------------------|
| Environmental Impacts | 0.4234 | 42.34% | 4.234 |
| Socio-Cultural Impacts | 0.2947 | 29.47% | 2.947 |
| Economical - Technical Impacts | 0.2819 | 28.19% | 2.819 |

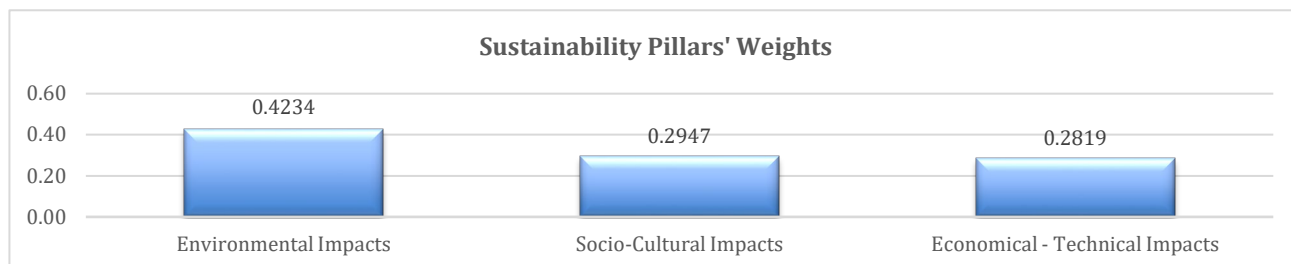
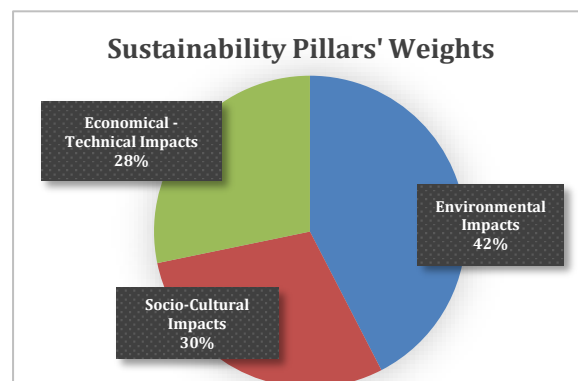


Fig. (19) Questionnaire Analysis, Main categories' weight Analysis, Source: Author

Objective 2- Individual Indicator Weights identification

Weighting assessment of indicators in each category of constructed wetland parks, according to the equation:

$$WAI = \frac{\sum f_i w_i}{\sum f_i}$$

Where: f_i = frequency of respective respondents

w_i = weight of each score value:

1 (not important) = 0.2

2 (slightly important) = 0.4

3 (moderately important) = 0.6

4 (Important) = 0.8

5 (very important) = 1

For example, calculations for Q8_ Community awareness in Socio - Cultural indicators weight

| Q8_ Community awareness of the project main functions | Respondents | Score Weight | Respondents Percent |
|---|-------------|--------------|---------------------|
| 1 Least Importance | 0 | 0.2 | 0.00% |
| 2 Low Importance | 3 | 0.4 | 2.88% |
| 3 Medium Importance | 22 | 0.6 | 21.15% |
| 4 Important | 37 | 0.8 | 35.58% |
| 5 Most Important | 38 | 1 | 36.54% |
| Preferred not to mention | 4 | | 3.85% |
| Total | 104 | | 100% |

$$\begin{aligned}
 WAI &= \frac{\sum \# \text{ Respondents} * \text{Score Weight}}{\sum \# \text{ Respondents}} = \\
 &= \frac{(0*0.2)+(3*0.4)+(22*0.6)+(37*0.8)+(38*1)}{(104 - 4)} \\
 &= \frac{82}{100} = 0.82
 \end{aligned}$$

∴ WAI of Community awareness in Socio - Cultural indicators = 0.82

Fig. (20) Questionnaire Analysis, Question 8 example for impact's weight calculations, Source: Author

Part 1: Weighting Socio - Cultural indicators of constructed wetland parks:

| Socio-Cultural Impacts | WAI Percent | Indicator Weight |
|--|-------------|------------------|
| Q7_ Community size served by the project | 75.80% | 0.8 |
| Q8_ Community awareness of the project main functions | 82.00% | 0.8 |
| Q9_ Community acceptance of the project | 84.16% | 0.8 |
| Q10_ Education / Training during construction and operation phases | 82.20% | 0.8 |
| Q11_ Public participation during construction and operation phases | 79.80% | 0.8 |
| Q12_ Increased recreational & social activities | 86.40% | 0.9 |
| Q13_ Added social, connectivity and safety values during construction & operation phases | 83.40% | 0.8 |
| Q14_ Visual / Aesthetic values of the project | 86.20% | 0.9 |
| Q15_ Odor reduction efficiency during operation phase | 81.21% | 0.8 |

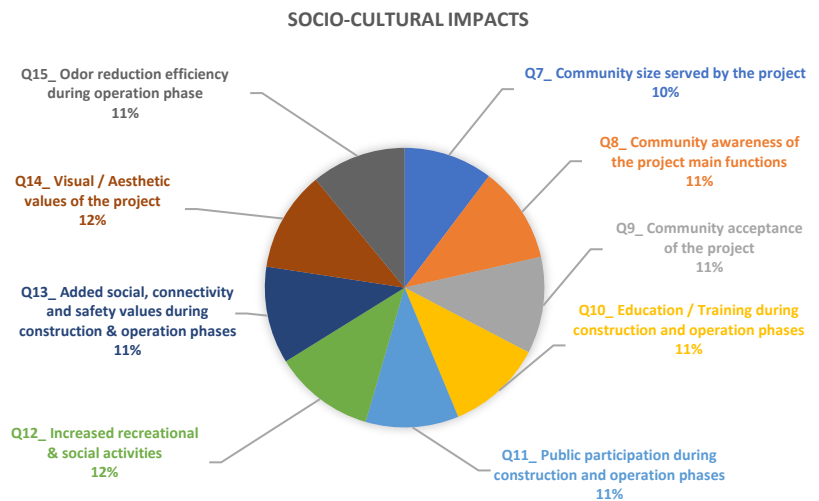


Fig. (21) Questionnaire Analysis, Qs 7 to 15, Socio - Cultural indicators' weights, Source: Author

Part 2: Weighting Economic - Technical indicators of constructed wetland parks:

| Economical-Technical Impacts | WAI Percent | Indicator Weight |
|--|-------------|------------------|
| Q16_ Catalyzing economic development | 77.17% | 0.8 |
| Q17_ Land use value | 82.83% | 0.8 |
| Q18_ Economic savings | 78.99% | 0.8 |
| Q19_ Potentials of economic revenue | 75.56% | 0.8 |
| Q20_ Construction process flexibility | 78.99% | 0.8 |
| Q21_ Operation and maintenance process flexibility | 83.40% | 0.8 |
| Q22_ Potential for future upgrading of project | 85.00% | 0.9 |

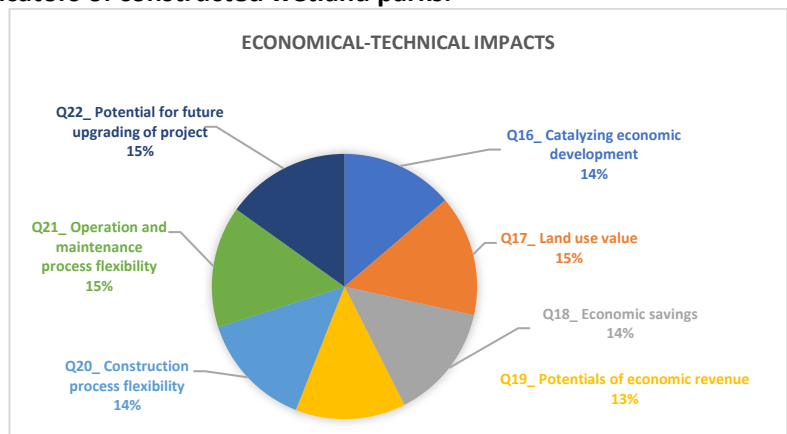


Fig. (22) Questionnaire Analysis, Qs 16 to 22, Economic - Technical indicators' weights, Source: Author

Part 3: Weighting Environmental indicators of constructed wetland parks:

| Environmental Impacts | WAI Percent | Indicator Weight |
|--|-------------|------------------|
| Q23_ Air quality during construction phase | 75.56% | 0.8 |
| Q24_ Air quality during operation phase | 86.46% | 0.9 |
| Q25_ Urban micro-climate during construction phase | 69.20% | 0.7 |
| Q26_ Urban micro-climate during operation phase | 85.86% | 0.9 |
| Q27_ Carbon footprint during construction phase | 72.20% | 0.7 |
| Q28_ Carbon footprint during operation phase | 83.84% | 0.8 |
| Q29_ Noise during construction phase | 68.37% | 0.7 |
| Q30_ Noise during operation phase | 78.20% | 0.8 |
| Q31_ Energy consumption during construction phase | 71.22% | 0.7 |
| Q32_ Energy consumption during operation phase | 83.67% | 0.8 |
| Q33_ Material use during construction phase | 78.38% | 0.8 |
| Q34_ Material use during operation phase | 81.01% | 0.8 |
| Q35_ Solid / Liquid wastes during construction phase | 78.78% | 0.8 |
| Q36_ Solid / Liquid wastes during operation phase | 81.22% | 0.8 |
| Q37_ Soil quality | 81.22% | 0.8 |
| Q38_ Flora enhancement | 86.19% | 0.9 |
| Q39_ Fauna enhancement | 81.46% | 0.8 |
| Q40_ Water quality during operation phase | 89.29% | 0.9 |

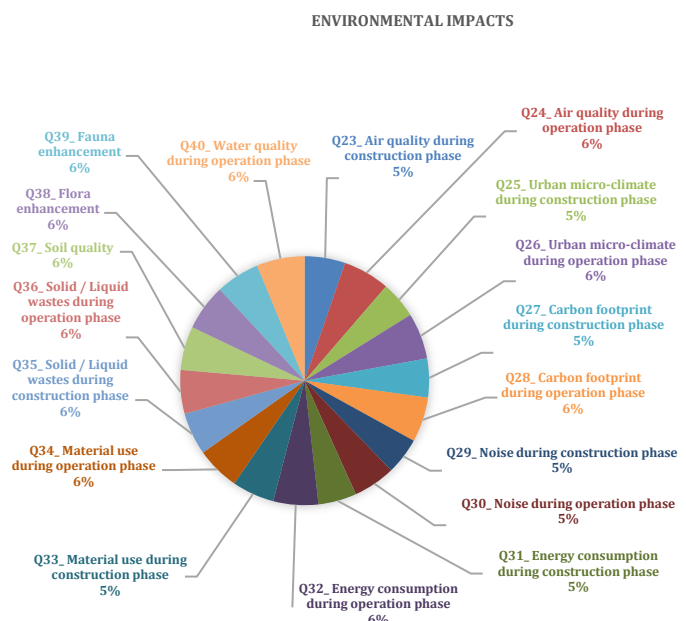


Fig. (23) Questionnaire Analysis, Qs 23 to 40, Environmental indicators' weights, Source: Author

3.3.6.3. Result:

During the participation of the author in a 2-day conference held in Egypt about constructed wetlands and having the chance to share the questionnaire amongst the participants in a short session describing the objective of the questionnaire and offering detailed instruction for participation, a great participation from more than 30 participants was achieved, this also helped in reaching more than double the amount of participations required, a minimum requirement of 50 participants to reach optimum indicative results.



Fig. (24) Questionnaire's sharing during international conference "Visions for Future Cities", Egypt, Source: Conference's Organizing Committee, VFC 2021, Date Taken: November 27, 2021, at 13:45 – 14:45

From diverse sharing of the questionnaire through various online platforms, 104 participants contributed to the questionnaire form at least 18 countries, where the results included variation in some perceptions, and similarity in others. However, there were great similarity in weighting impacts between different countries with different environmental, culture and economic values. Though some showed great interest in the economic impact of constructed wetlands, others showed more to the environmental or social impacts. This shows that the three sustainability pillars are of a great importance and not to be neglected in the assessment process as suggested by the thesis.

Evaluation of the weights of the 3 indicators categories of sustainability

| Sustainability Pillars' Weights | WAI Impact Weight | Percent from Total | Impacts Sustainability Score |
|---------------------------------|----------------------|-----------------------|---------------------------------|
| Environmental Impacts | 0.4234 | 42.34% | 4.234 |
| Socio-Cultural Impacts | 0.2947 | 29.47% | 2.947 |
| Economical - Technical Impacts | 0.2819 | 28.19% | 2.819 |
| Total | 1 | 100% | 10 |

Fig. (25) Questionnaire Analysis, Main Categories' weights, Source: Author

These weights are used to evaluate each category's sustainability achievement,

Evaluation of Park's Sustainability achievement

Park's Achieved Sustainability Score from 10 = Environmental Sustainability Score
+ Socio-Cultural Sustainability Score
+ Economical - Technical Sustainability Score

Category's Achieved Sustainability Score

Category's Sustainability Achievement Score from 10 = $\sum \frac{\text{Category impact Score}}{\text{Max Score}} * \text{Category Weight}) * 10$

Defining Weights of indicators in achieving sustainability goals and targets in both construction and operation phases, according to their relative importance

| Socio-Cultural Impacts | WAI Percent | Indicator Weight |
|--|------------------------|-----------------------------|
| Q7_ Community size served by the project | 76.40% | 0.8 |
| Q8_ Community awareness of the project main functions | 82.60% | 0.8 |
| Q9_ Community acceptance of the project | 82.97% | 0.8 |
| Q10_ Education / Training during construction and operation phases | 82.20% | 0.8 |
| Q11_ Public participation during construction and operation phases | 79.80% | 0.8 |
| Q12_ Increased recreational & social activities | 86.40% | 0.9 |
| Q13_ Added social, connectivity and safety values during construction & operation phases | 83.40% | 0.8 |
| Q14_ Visual / Aesthetic values of the project | 86.20% | 0.9 |
| Q15_ Odor reduction efficiency during operation phase | 81.21% | 0.8 |

Fig. (26) Questionnaire Analysis, Socio-Cultural Impacts' weights, Source: Author

| Economical-Technical Impacts | WAI Percent | Indicator Weight |
|--|------------------------|-----------------------------|
| Q16_ Catalyzing economic development | 77.17% | 0.8 |
| Q17_ Land use value | 82.83% | 0.8 |
| Q18_ Economic savings | 78.99% | 0.8 |
| Q19_ Potentials of economic revenue | 75.56% | 0.8 |
| Q20_ Construction process flexibility | 78.99% | 0.8 |
| Q21_ Operation and maintenance process flexibility | 83.40% | 0.8 |
| Q22_ Potential for future upgrading of project | 85.00% | 0.9 |

Fig. (27) Questionnaire Analysis, Economical-Technical Impacts' weights, Source: Author

| Environmental Impacts | WAI Percent | Indicator Weight |
|--|------------------------|-----------------------------|
| Q23_ Air quality during construction phase | 75.56% | 0.8 |
| Q24_ Air quality during operation phase | 86.46% | 0.9 |
| Q25_ Urban micro-climate during construction phase | 69.20% | 0.7 |
| Q26_ Urban micro-climate during operation phase | 85.86% | 0.9 |
| Q27_ Carbon footprint during construction phase | 72.20% | 0.7 |
| Q28_ Carbon footprint during operation phase | 83.84% | 0.8 |
| Q29_ Noise during construction phase | 68.37% | 0.7 |
| Q30_ Noise during operation phase | 78.20% | 0.8 |
| Q31_ Energy consumption during construction phase | 71.22% | 0.7 |
| Q32_ Energy consumption during operation phase | 83.67% | 0.8 |
| Q33_ Material use during construction phase | 78.38% | 0.8 |
| Q34_ Material use during operation phase | 81.01% | 0.8 |
| Q35_ Solid / Liquid wastes during construction phase | 78.78% | 0.8 |
| Q36_ Solid / Liquid wastes during operation phase | 81.22% | 0.8 |
| Q37_ Soil quality | 81.22% | 0.8 |
| Q38_ Flora enhancement | 86.19% | 0.9 |
| Q39_ Fauna enhancement | 81.46% | 0.8 |
| Q40_ Water quality during operation phase | 89.29% | 0.9 |

Fig. (28) Questionnaire Analysis, Environmental Impacts' weights, Source: Author

Chapter 4: Case Studies

Introduction

For better understanding of different environmental assessment and performance of different wetland parks. The thesis discusses the performance of five different wetland projects from different countries and with different approaches and types. Each is discussed in detail then an assessment table is prepared to discuss the environmental impact assessment of each of them and finally a comparative assessment table will be showing the different environmental benefits reached for the five cases.

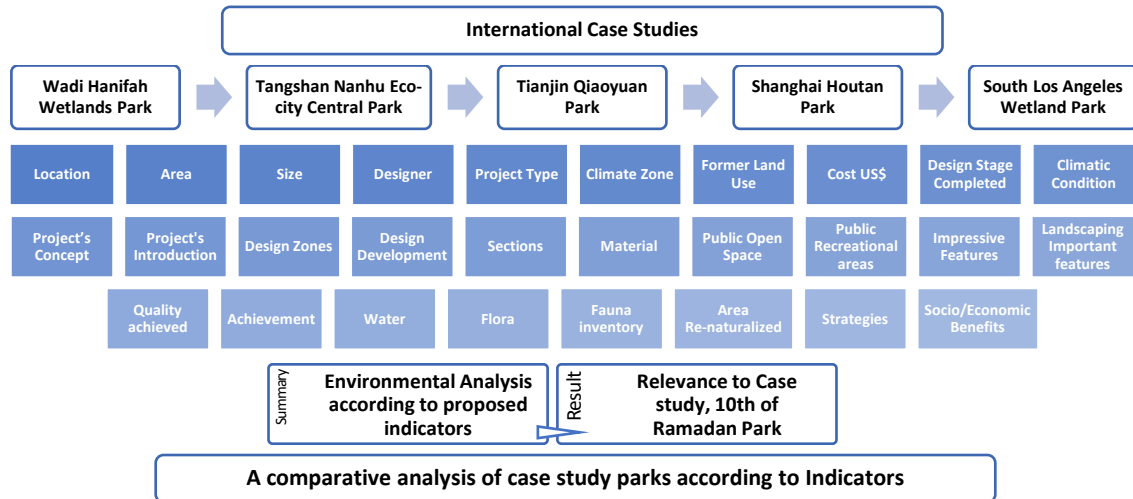


Fig. (29) Chapter 4, Methodology and structure, Source: Author

The criteria of Parks selection were:

- Wetland creation/restoration
- Multifunctional Parks
- Construction Timeframe: within 15 years
- Brownfield
- Different Climatic Zones (Arid, Cold, Humid continental, Humid subtropical, Mediterranean)
- Various Scale Parks (Large-scale, Medium-scale and Small-scale Parks)

Case Studies

Case 1: Wadi Hanifah Wetlands Park

Location: Riyadh, Saudi Arabia, 2010

Climate Zone: Arid, Hot desert

Case 2: Tangshan Nanhu Eco-city Central Park

Location: Tangshan, China, 2009

Climate Zone: Humid continental

Case 3: Tianjin Qiaoyuan Park

Location: Tianjin, China, 2008

Climate Zone: Cold semi-arid

Case 4: Shanghai Houtan Park

Location: Shanghai, China, 2010

Climate Zone: Humid subtropical

Case 5: South Los Angeles Wetland Park

Location: Los Angeles, USA, 2011

Climate Zone: Hot-summer Mediterranean

4.1 Wadi Hanifah Wetlands Park

4.1.1 Introduction:

Location: Riyadh, Saudi Arabia, 2010

Climate Zone: Arid, Hot desert

Scale: Large-scale Park; 15 km²



Fig. (30) Wadi Hanifah Site Location, Source: Google Earth, Date accessed: Sep. 1, 2021



Fig. (31) Wadi Hanifah Wetland Park's Location, Source: Google Earth, edited by Author, Date accessed: Sep. 1, 2021

4.1.2 Analysis:

Case Study 1 Wadi Hanifah Wetlands Park

| | |
|-------------------------------|---|
| Location | Riyadh, Saudi Arabia, 24°33'08.5"N 46°44'29.0"E |
| Area | Park: 15 million m ² , 15 km ² , 3,709 acres (Large-scale Parks), Total: 4,000 km ² over a 120 km stretch |
| Sizes | Drainage basin: 1,738 sq miles; riverbed: 74.6 miles; designed urban parkland: 3,709 acres |
| Designer | Moriyama & Teshima Planners Limited & Buro Happold in joint venture |
| Project Type | Park/Open space Stream restoration Wetland creation/restoration / Waterfront redevelopment |
| Climate Zone | Arid, Hot desert |
| Former Land Use | Brownfield Parts of the valley were used as dumping grounds for rubbish; other parts were quarried for stone or sand |
| Cost US\$ | 160 million, Budget: \$1 billion |
| Design Stage Completed | 2001 to 2004 - Master Plan development, Restoration Designs, and design of Enhancements. Construction/ Implementation Period: 2004 till 2010. |
| Climatic Condition | Rainfall is scarce in this area, with an annual average of 85 millimetres. During the months of March and April, more than half of this occurs. In the Riyadh area, temperatures range from a low of 6.4°C in January to a high of 42.9°C in July. (Al-Asad, M. et al., 2004; Samhouri, W., 2010; Alrabe, M., 2015) |
| Project's Concept | <ol style="list-style-type: none"> 1. Environmental and sustainable Approach 2. Water demand management 3. Land use and activities 4. Rehabilitation of the valley 5. Controlling and conditions |

The longest and most important valley near Riyadh is Wadi Hanifah (the Hanifah Valley). It's a one-of-a-kind natural geographical feature in central Saudi Arabia's desert region of Najd. The valley is a natural water drainage system for an area of nearly 4,000 square kilometers, and it is fed by several streams. It travels from northwest to southeast, going through Riyadh's western outskirts in the center. The valley includes a continuous river from this center point, resulting from the daily discharge of 650,000 cubic meters of treated and untreated water. This year-round flow of water has created a one-of-a-kind occurrence in the parched environment's lush sections. (AKAA, 2008)

Parts of Wadi Hanifah, particularly those near Riyadh, had been used in an aggressive and environmentally harmful manner until recently. Some areas of the valley were utilized as garbage dumps, while others were quarried for stone or sand. As a result, a large portion of the valley has been damaged and polluted, and portions of its terrain have been drastically altered. The natural flow of water has been impeded in some areas, resulting in stagnant pools and swamp-like situations. (AKAA, 2008; Al-Asad, M. et al., 2004)

Picnicking, fishing, and swimming are all common leisure activities in the wetlands to the south of the valley. Unfortunately, the picnickers have littered the area. Fishing and swimming in the valley can be dangerous due to the filthy waters (average 200,000 m³ daily) released into the valley. (Al-Asad, M. et al., 2004)

Since the 1980s, the Arriyadh Development Authority (ADA, the Higher Commission for the Development of Arriyadh) has conducted research on Wadi Hanifah. In 1994, a development strategy plan was proposed and formally accepted. A full development plan for the valley was commissioned in 2001, the research was finished in 2003, and implementation began in early 2004. The plan was ongoing and long-term, although most of its components were completed by 2007. (Al-Asad, M. et al., 2004; Samhouri, W., 2010)

Introduction

Design Zones



Fig. (32) Five design Zones make up the Wadi Hanifa Project, Source Alrabe, M., 2015, edited by Author

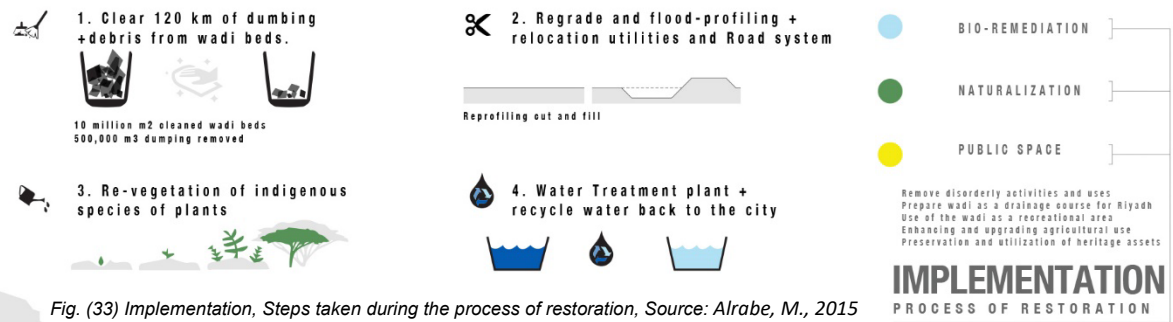


Fig. (33) Implementation, Steps taken during the process of restoration, Source: Alrabe, M., 2015

Design Development



Fig. (34) Wadi Hanifah Bioremediation site, Source: Google Earth, Date accessed: Jan. 24, 2022

The bio-remediation system now has **three compartments**, while there were four in the original design, due to the significant cost of rerouting some of the bigger services buried inside the wadi bed, the size was reduced. To compensate for this reduction the cells from the unrealized compartment were **rearranged in the third compartment**, ensuring that the facility's operation was not compromised. (Samhouri, W., 2010)

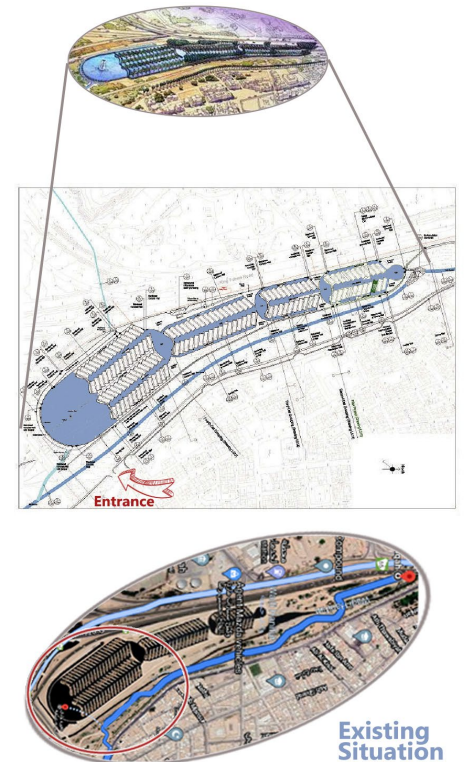


Fig. (35) Existing situation, Source: Author from Stockton, G., et al., 2010, RCRC, Google Map, Date accessed: June 2020

Sections

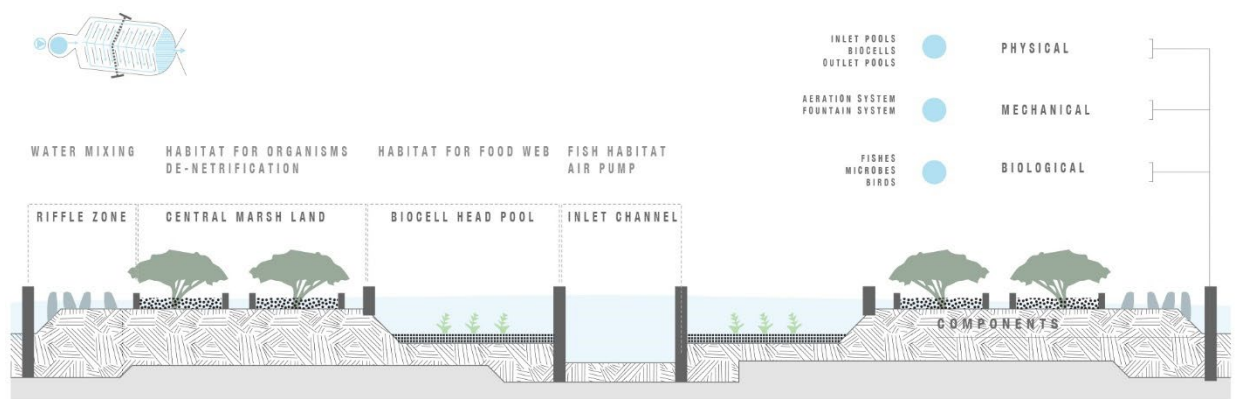


Fig. (36) Bioremediation Components section, Source: Alrabe, M., 2015

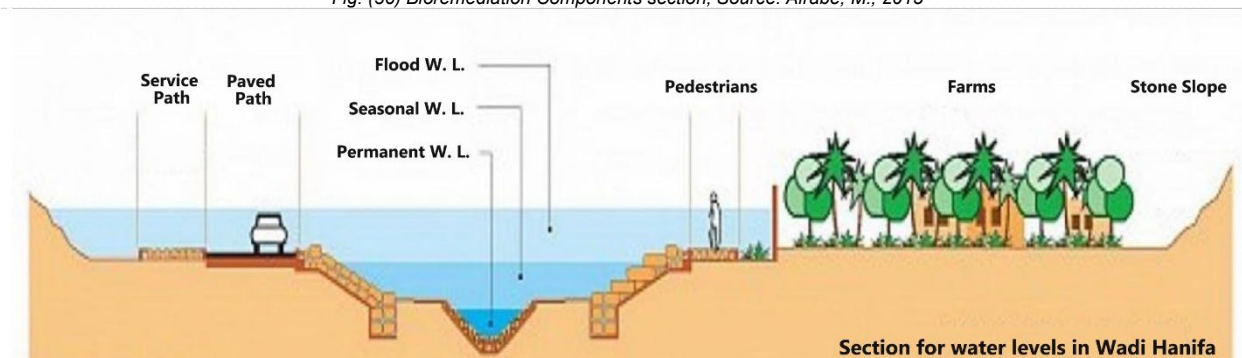


Fig. (37) Water levels section in Wadi Hanifah, Source: Edited by Author from <https://www.alriyadh.com/518208>, 2010, Date accessed: June 19, 2020

Material

Natural materials were used to construct the Bio-remediation Facility

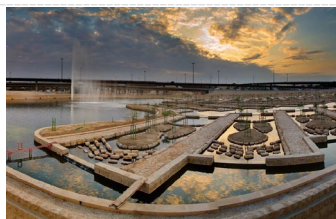
A sequence of natural stone weirs was created to assist minimize pollution in the Wadi by introducing oxygen into the water as it travels over and through them, Fig.(37). Construction of check dams in the desert tablelands and rangelands in the desert catchment area above the Wadi bed to restore the natural landscape, Fig. (38) (Samhour, W., 2010)



Fig. (38) Natural stones Weirs and Restoring natural landscape
Source: AKAA, 2008



Public Open Space



This project has already proven to be a success in terms of water treatment and the creation of a one-of-a-kind natural facility and public open-space attraction. (Samhour, W., 2010; Salama, N. et al., 2015)

Fig. (39) Wadi Hanifah open-space attraction, Source: AKAA, 2008

Public Recreational areas



The parks' design enhances the idea that each family has their own family compartment in the form of semi-enclosed sections that they can enjoy for the day without being disturbed by other families. To encourage early public participation and use of the Wadi ecosystem, a large portion of the Wadi Bed Naturalized Parkland and Recreational and Interpretative Trail is being developed. (Samhour, W., 2010)

Fig. (40) Family booths and semi-enclosed sections, Source: Arriyadh DA/Moriyama & Teshima/Buro Happold, 2010

Impressive Features

One of the project's most striking aspects is the Bio-remediation Facility



There are **134 individual cells** in the bio-remediation system, configured in a herring-bone arrangement. The **cells are designed** to have the **same amount of water flowing** at the same time and to **keep the water within the cells as long as possible**, in order for the various parts of the cell to act on the water to reduce the amount of pollution. (Samhour, W., 2010)

Fig. (41) Bio-remediation individual cells, Source: AKAA, 2008; Samhour, W., 2010



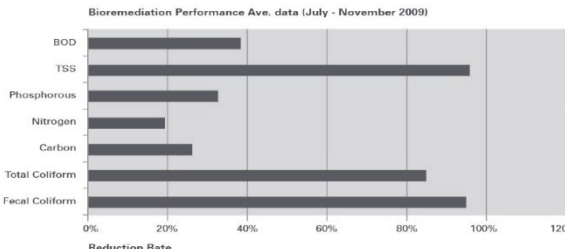
Landscaping Important features

- **Rock features** to introduce an interesting natural feel to the wadi.
- **Planting of Native palm trees** at some of the gateways to Riyadh.
- **Landscaping cells of indigenous species of flora** that **occur naturally** in the wadi and are proven to be hardy in the harsh environment. Through natural regeneration these will spread throughout the wadi.
- **Interpretative trails** that wind their way throughout the wadi allowing the public to access the area easily and to direct them to places of interest.
- The interpretative trails and wadi roads will be **lit to allow safe access** through the area during the cooler night period
- **Lighting** to provide an **interesting ambience** to the wadi by lighting up **certain features**, such as rock escarpments, to bring an interesting look.
- **Using existing features** to create interesting landscapes.
- **Creation of lakes and parks for recreational purposes.** Five large parks.
- Prayer areas. - Toilet blocks. - Interpretative signage has been introduced. Source: Samhour, W., 2010

Quality achieved:

- 120 km in length
- 500,000 m3 dumping removed
- 10 million m2 cleaned wadi bed
- 2.5 million m3 in reprofiling cut and fill 40 side Wadis (10 major wadis)
- 7.4 km pedestrian promenades
- 46.8 km of recreational trails created
- 30 toilet blocks designed and built
- Bio-remediation Facility consisting of 134 bio-remediation cells designed and built
- 42.8 km of Wadi roads
- 2,000 parking spaces created
- 730 pieces of wayfinding and interpretive signage
- 2,500 light standards along walking trails and wadi roads
- 600 pieces of feature lighting

Source: Arriyadh DA/Moriyama & Teshima/Buro Happold, 2010

| | <div> <div>BEFORE</div>  </div> <div> <div>AFTER</div>  </div> | | | | | | | | | | | | | | | | |
|-------------------------|---|-----------|--------------------|-----|-----|-----|-----|-------------|-----|----------|-----|--------|-----|----------------|-----|----------------|-----|
| Achievement | <div> <div>Fig. (42) Wadi Hanifah location before construction,</div> <div>Source: LPS-CSB-1015, 2015</div> <div>Fig. (43) Park after Construction</div> </div> | | | | | | | | | | | | | | | | |
| Water | <ul style="list-style-type: none"> • 350,000 cubic meters of urban wastewater cleaned per day (2010) • 1,200,000 cubic meters of urban wastewater cleaned per day expected in 2025 <p>5 lakes created (25.1 hectares total surface area) Source: Arriyadh DA/Moriyama & Teshima/Buro Happold, 2010</p> <div>  <p>Bioremediation Performance Ave. data (July - November 2009)</p> <table border="1"> <thead> <tr> <th>Pollutant</th> <th>Reduction Rate (%)</th> </tr> </thead> <tbody> <tr> <td>BOD</td> <td>~40</td> </tr> <tr> <td>TSS</td> <td>~95</td> </tr> <tr> <td>Phosphorous</td> <td>~35</td> </tr> <tr> <td>Nitrogen</td> <td>~20</td> </tr> <tr> <td>Carbon</td> <td>~25</td> </tr> <tr> <td>Total Coliform</td> <td>~85</td> </tr> <tr> <td>Fecal Coliform</td> <td>~90</td> </tr> </tbody> </table> <p>Fig. (44) Bioremediation performance in 2009, Source: Arriyadh DA/Moriyama & Teshima/Buro Happold, 2010</p> </div> | Pollutant | Reduction Rate (%) | BOD | ~40 | TSS | ~95 | Phosphorous | ~35 | Nitrogen | ~20 | Carbon | ~25 | Total Coliform | ~85 | Fecal Coliform | ~90 |
| Pollutant | Reduction Rate (%) | | | | | | | | | | | | | | | | |
| BOD | ~40 | | | | | | | | | | | | | | | | |
| TSS | ~95 | | | | | | | | | | | | | | | | |
| Phosphorous | ~35 | | | | | | | | | | | | | | | | |
| Nitrogen | ~20 | | | | | | | | | | | | | | | | |
| Carbon | ~25 | | | | | | | | | | | | | | | | |
| Total Coliform | ~85 | | | | | | | | | | | | | | | | |
| Fecal Coliform | ~90 | | | | | | | | | | | | | | | | |
| Flora | <ul style="list-style-type: none"> • 9 major parks created, new landscapes: 30,000 shade trees planted; 6,000 planted date palms; 50,000 shrubs planted; 2,000 large Acacia transplanted (Salama, N. et al., 2015) • The re-naturalized area includes 1,805 planting cells in 35 distinct configurations¹ including a total of: 28,021 trees (7 different species or varieties); 40,166 shrubs (20 different species or varieties); 44,719 grasses (8 species); 33.54 seeded grasses acres; 1.38 seeded perennials acres (Trottier, J., et al., 2015) | | | | | | | | | | | | | | | | |
| Fauna inventory | <p>Birds: Bittern, egret, mallard duck, heron, long-beaked bird sp. (unidentified), moorhen, black-winged stilt, woodpecker, eagle, seagull, mynah, house sparrow, spotted dove, pigeon, kingfisher</p> <p>Fish: Tilapia, African jewelfish (cichlid), molly (sailfin and black-spotted), gambusia (mosquito fish), African and sucker mouth catfish, koi carp; Mollusks: Melanoide snail, ram horn snail, Asian clam;</p> <p>Amphibians: Frog sp., turtle sp.; Reptiles: Common house gecko, Arabian spiny-tailed lizard, water snake;</p> <p>Insects: Grasshopper, dragonfly, honeybee (Trottier, J., et al., 2015)</p> | | | | | | | | | | | | | | | | |
| Area Re-naturalized | <p>WH Zone 2: area = 1,030.5 acres, Planting cells area = 26.2 acres, Percentage vegetated area = 2.5%, WH Zone 3: area = 1,443.6 acres, Plantation cells area = 61.3 acres, Percentage vegetated area = 4.2% WH Zone 4: area = 1,234.8 acres, Plantation cells area = 27.3 acres, Percentage vegetated area = 2.2%</p> <p>Wadi Hanifah Total Re-Naturalized Area: Overall project area = 3,708.9 acres, Plantation cells total area = 114.9 acres, Seeded area = 34.9 acres, Total new vegetated area = 149.8 acres, Percentage vegetated area = 4.0% (Trottier, J., et al., 2015)</p> | | | | | | | | | | | | | | | | |
| Strategies | <p>Environmental Strategies:</p> <ul style="list-style-type: none"> • Resilient well-managed ecosystems, management strategies for functional ecosystems • Arabian wetlands conservation strategy and biodiversity preservation • Conservation of water resources, mitigation of the effects of climate change • National wetland policies implementation and adoption <p>Social Strategies</p> <ul style="list-style-type: none"> • Promote Green Space for Public Recreation <p>Economic Strategies</p> <ul style="list-style-type: none"> • Reduce economic hardship at the community level • Combining economic growth with environmental conservation (Al-Obaid, S., et al., 2017) | | | | | | | | | | | | | | | | |
| Socio/Economic Benefits | <p>SOCIAL: Attracts 200,000 visitors per week, re-establishing the social, cultural, and recreational significance of the wadi for Riyadh residents. Generates no offensive odors due to an average dissolved oxygen concentration of 6.54 at the facility's outlet.</p> <p>ECONOMIC: Saves around \$27 million per day, the cost of 253,000 barrels of oil that would be required for desalinization and reduces reliance on seawater as a water source. (LPS-CSB-1015, 2015)</p> | | | | | | | | | | | | | | | | |

4.1.3 Case study's Environmental Analysis Summary according to proposed indicators

Table (6) Wadi Hanifah Park's Environmental Analysis Summary, Source: Author, from Trottier, J., et al., 2015

| Category | Indicator | Sub-Indicators /Description | Type | Output |
|-----------------------|---------------------------------|--|--------------|--|
| Environmental Aspects | Climatic Aspects | Air Quality - Air quality: Improvement in air quality due to increased vegetation cover | Quantitative | Sequesters 89,144.9 lbs. of atmospheric carbon annually in 28,021 newly planted trees. Total new vegetated area = 149.8 acres, Percentage vegetated area = 4.0% |
| | | Urban Micro-Climate - Heat Island Effect: % of decrease in Heat Island Effect due to increased vegetation cover and water bodies | Quantitative | |
| | | Carbon Footprint - Carbon Footprint: amount of carbon dioxide and other GHG emissions associated with the wetland project compared to conventional treatment plant | Quantitative | |
| | Sustainability | Energy - Construction Energy Conservation: % of energy conserved during construction stage compared to conventional treatment plant - Operation Energy conservation: % of operational electrical energy conserved compared to conventional treatment operations measured over a specific temporal scale | Quantitative | No Data Available |
| | | Materials - Recycled Materials: % of materials that is recycled or acquired from onsite materials - Hazardous Materials: % of hazardous materials and chemicals employed in water treatment process compared to conventional treatment processes | Quantitative | <ul style="list-style-type: none"> The Bio-remediation Facility is all built with natural materials. Re-establishing the natural landscape in the desert tablelands A series of natural stone weirs were built |
| | | Solid/ Liquid Wastes - Quality/ Quantity of wastes: % of waste materials discharged during the treatment process | Quantitative | <ul style="list-style-type: none"> Removal of 17.7 million cu ft of industrial and municipal wastes from an area of 4 sq miles, enough to fill a football stadium. Suspended solids ≤30 mg/L |
| | | Soil - Quality/ Quantity of soil creation, preservation & restoration: % of fertile or restored soils | Quantitative | No soil samples were available to confirm soil quality |
| | Biodiversity; Habitat Diversity | Flora (Vegetation) - Number of Fauna and Flora species introduced into the habitat | Quantitative | Re-naturalizes 115 acres with native plant species and 35 acres with seeded native grasses and perennials to improve riparian habitat. Between 2010 and 2015, these areas grew by 47 acres through self-propagation |
| | | Fauna - Number of Fauna and Flora species introduced into the habitat | Quantitative | According to site observation, it supports 15 bird species, 9 fish species, 3 mollusk species, 2 amphibian species, and 3 reptile species. |
| | Water | Water Reused - Water Reused: % of water reused or reintroduced to the irrigation system. | Quantitative | <ul style="list-style-type: none"> Average of 92.5 million gallons of treated urban wastewater per day, with a capacity of 317 million gallons per day estimated by 2025, comparable to 1.5 bathtubs per Riyadh inhabitant each day. Urban wastewater cleansed/day, 350,000 m³ (2010) Urban wastewater cleansed/day, 1,200,000m³ by 2025 Use of bioremediated urban wastewater for park facilities and irrigation reduces potable water usage by 92.5 million gallons per day. Maintains dissolved oxygen concentrations above 6 mg per liter, which is considered enough for maintaining healthy aquatic habitats. |
| | | Water Quality - Water quality: % of pathogens removed through the constructed wetland | Quantitative | Removes 33% phosphorus, 13.5% nitrogen, 89% faecal coliforms, 79% total coliforms, and 94% total suspended particles on average from urban wastewater. After treatment, the levels of faecal coliform in the water are safe for occasional human contact. |

4.1.4 Relevance to Case study, 10th of Ramadan Park

1- Material:

Use of natural stone and local materials

2- Public Open Space

Providing water treatment while creating a unique open-space public attraction.

3- Public Recreational areas

- Respecting cultural and social values in the park's design and offering family compartments, and semi-enclosed areas that respect users' privacy
- Developing a major part of the park to get early public participation.

4- Landscaping Important features

- Enriching the aesthetic value with greenery and water features.
- Development of various landscape features to offer diverse aesthetic usage of the park, for example:
 - **Rock features** to introduce an interesting natural feel
 - **Planting of Native** palm trees and various ornamental indigenous species of flora
 - **Landscaping of diverse zones** with various themes for interactive experience
 - **Interpretative trails** to allow public to access and guiding to places of interest
 - **Interesting ambience with lighting** to show certain features that bring an interesting look.
 - **Use of existing features** in creating interesting landscapes.
 - **Designing of lakes, ponds and parks** for recreational purposes and dynamic user experience
 - **Respecting social and religious value** by offering Prayer areas, Toilet blocks, and activity booths
 - **Interpretative signage** for guidance through the park

5- Flora

Re-naturalization with indigenous species of shading trees, ornamental shrubs and aromatic perennials

6- Fauna inventory

Enriching the environment with diverse indigenous habitat of various fauna, i.e., Birds, Fish, Mollusks, Amphibians, Reptiles, Insects

7- Socio/Economic Benefits

SOCIAL:

- Attracting neighboring community and other visitors through offering a unique and interactive experiences and through designing various thematic zones that encourage visitors to experience the various activities.
- Encouraging community engagement through various activities and aesthetic values.
- Re-establishing the social, cultural, and recreational significance of the community.

ECONOMIC: Saving of a great cost value through utilizing water sources instead of desalinization

4.2 Tangshan Nanhu Eco-city Central Park

4.2.1 Introduction:

Location: Tangshan, China, 2009

Climate Zone: Humid continental

Scale: Large-scale Park; 0.63 km²

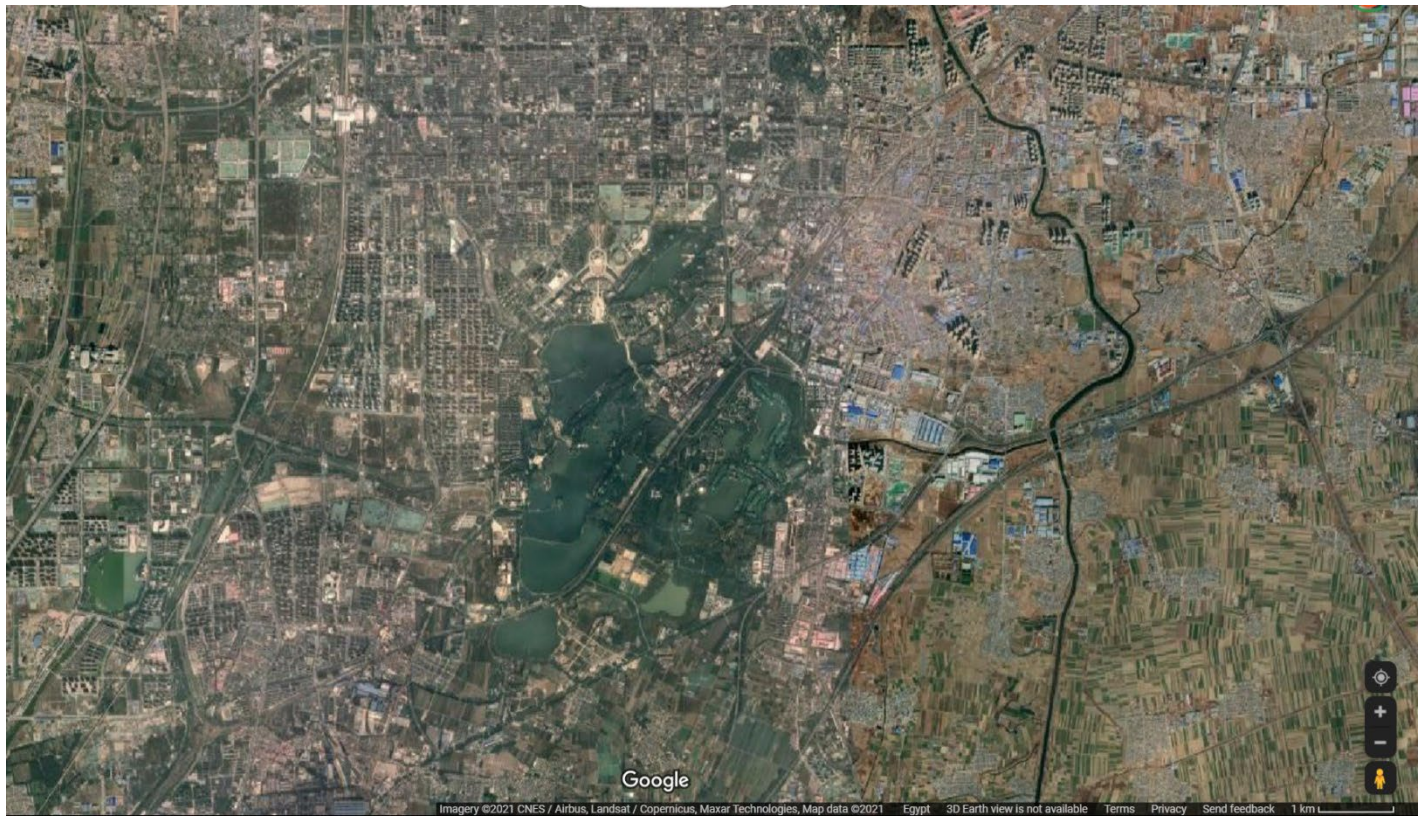


Fig. (45) Tangshan Nanhu Site Location, Source: Google Map, Date accessed: Sep. 1, 2021



Fig. (46) Tangshan Nanhu Wetland Park's Location, Source: Google Map, edited by Author, Date accessed: Sep. 1, 2021

4.2.2 Analysis:

Case Study 2 Tangshan Nanhu Eco-city Central Park

| | |
|--|--|
| Location | Tangshan, Hebei, China, 39°36'43.9"N 118°10'40.5"E |
| Area | 6.3 million square meters, 0.63 km ² , 1,557 acres (Large-scale Parks) |
| Designer | Beijing Tsinghua Urban Planning & Design Institute (THUPDI) |
| Project Type | Nature preserves (protection of urban nature) Park/Open space Wetland creation/restoration |
| Climate Zone | Humid continental |
| Former Land Use | Brownfield A coal mine reclamation project. A former 1,557-acre wasteland |
| Cost US\$ | \$68,027,648 |
| Completion | 2009 |
| Challenges & Site Condition | The coal mining sector is well-known in Tangshan City. Many mined sections at the project site collapsed after a large earthquake in 1976 and were used as a landfill and sewage lagoon. The wasteland was turned into northeastern China's largest urban central park in less than three years. (ULI Americas, 2013) |
| Project's Concept | Sustainable approaches such as materials reuse and recycling, stormwater management, erosion control, and wildlife habitat restoration are emphasized in the park design, which promotes the harmony between humans and environment. (ULI Americas, 2013) Convert the mining subsidence region into a new urban region with a beautiful environmentally friendly ecosystem that expresses humanism, which will eventually become a central park. (Yang, Y., et al., 2016) |

Introduction

Tangshan Nanhu Central Park is a mining reclamation project which began in 2008 and is currently Northeast China's largest urban central park. The former 1,557-acre wasteland, which is now a vibrant public space with recreational amenities, conservation areas, and over 600,000 trees and bushes, is in the heart of Tangshan City. After a massive earthquake in 1976, the former coal mining site was heavily polluted and damaged. Parts of the site had collapsed and settled unevenly, resulting in a patchwork of unstable surfaces covering 28 square kilometers. The site, which had become a safety hazard, was primarily used as a city landfill and sewage lagoon. The project has fundamentally enhanced the environmental quality of Tangshan City and established a main new public recreational space, which is accessible to more than 10,000 residents within a 15-minute walk, by employing sustainable methods such as material reuse, stormwater management, and wildlife habitat restoration. (LPS-CSB- 494, 2012)

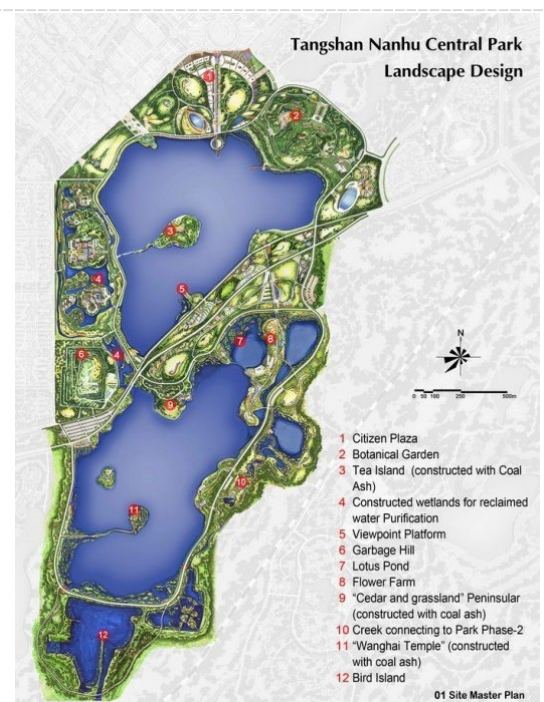
Design Zones

The site was a huge brownfield with a lot of toxic trash and sewage, as well as geological subsidence. The entire southern area of the land specifically was lacking in geotechnical stability. The concept proposed extremely varied usage and visual qualities north and south of the main separating road in response to the site's varying environmental conditions.

The park, located north of Tangxu Road, is geologically stable and is consequently ideally planned for active recreational activities, including features such as gardens, the recovered garbage hill, plazas, and pathways.

The area south of Tangxu Road has been planned as a natural reserve, with minimal human intervention to preserve the natural vegetation and landform. Cedar grasslands, marshes, and other native habitats can be found in this section of the park. The settling ground and shorelines in this area were mostly stabilized using items found on site, such as pebbles and dead tree wood supports. (LPS-CSB- 494, 2012)

Fig. (47) Park's Landscape Design, Source: LPS-CSB- 494, 2012



Weave waste plant materials together to form solid revetments.

The willow branches implanted along boardwalks sprouted the next spring, stabilizing the banks and providing shade for fish and wildlife.



Treat weak foundations first with timber piles to increase bearing capacity.

Then apply re-cycled coal ash, coal-ash concrete and other materials for roads.



Willow Sprouts



Fig. (48) The lakefront: was stabilized, load-bearing capacity was increased, and roads were constructed using waste plant materials and coal ash, Source: LPS-CSB- 494, 2012; Beijing Tsinghua Urban Planning & Design Institute; Biennial, An, Y., et al., 2014

Design Development

Ecological Techniques with Low-Carbon, Low-Impact, and Low-Cost:

In the Nanhu region, 450 metric tons of trash were recovered and utilized to build a hill of 50 m height with 130,000 m² of greenery. The slope was sealed, covered with topsoil, and trees were planted on top. It offers stunning vistas as well as a variety of leisure activities including strolling, hiking, and picnics. In the garbage hill, a waste gas collecting system captures and burns the gas produced by the garbage, keeping it from being released into the atmosphere. (LPS-CSB- 494, 2012)

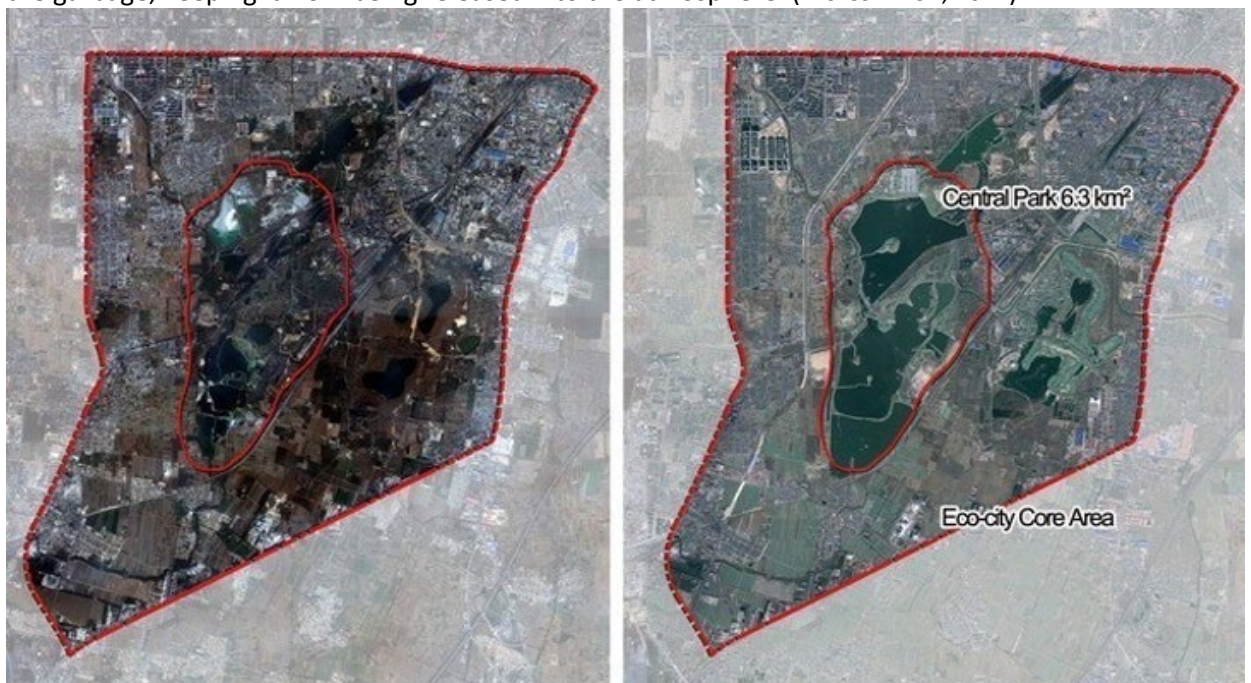


Fig. (49) Park's Satellite Images: Left - Prior to Construction on 08-07-2008, Right - Following Completion on 11-15-2010 Source: LPS-CSB- 494, 2012; Beijing Tsinghua Urban Planning & Design Institute

Analysis

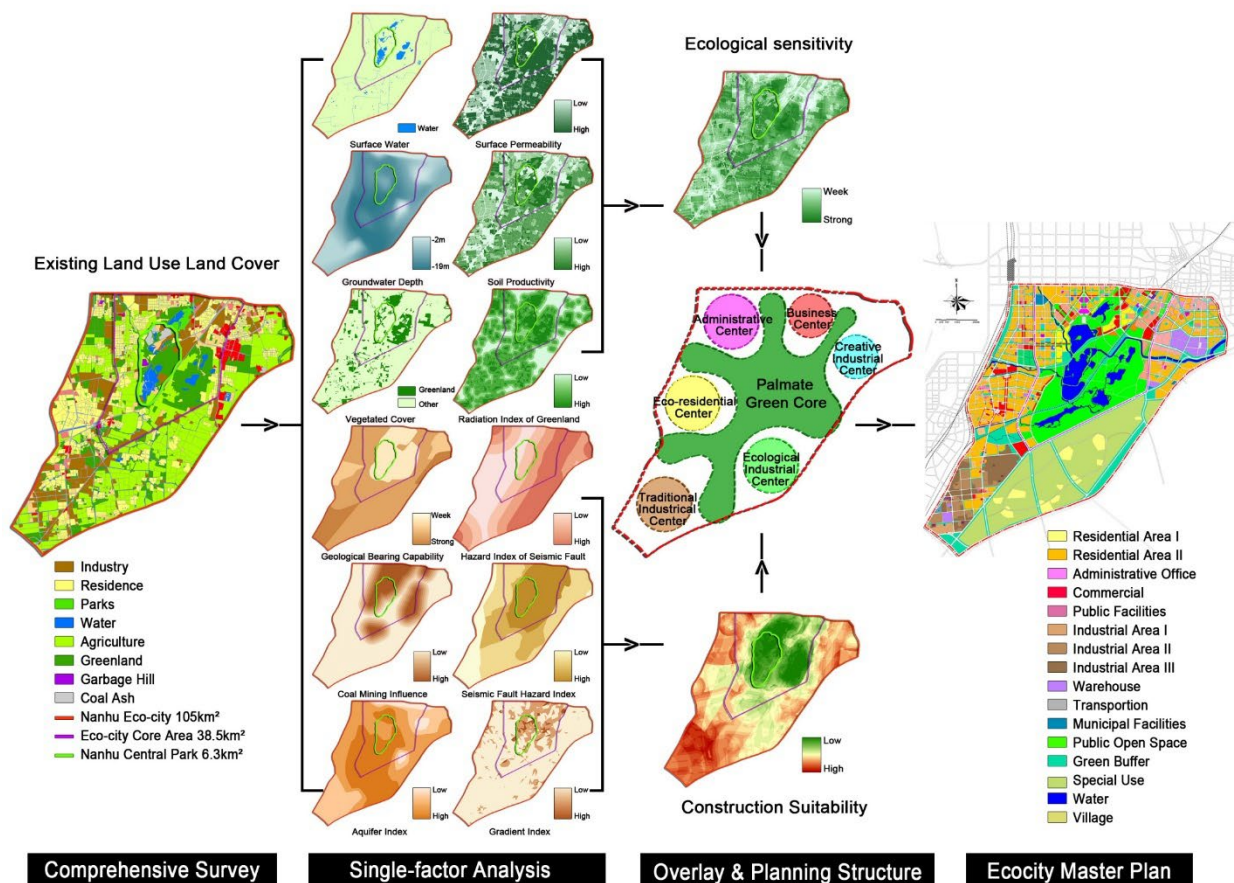


Fig. (50) GIS Overlay study: To define a stable foundation for land development in the ecocity region, a detailed GIS Overlay study was used.
Source: Biennal, An, Y., et al., 2014

Material

In the Nanhu area, 450 tons of trash were reclaimed and utilized to build a 50-meter-high hill with 130,000 square meters of green space, as the Rubbish Hill was stabilised, sealed, and replanted with native trees, shrubs, and wildflowers, offering a stunning vistas as well as a variety of recreational activities like strolling, hiking, walking and picnicking.



Fig. (51) The Rubbish Hill transformation
Source: LPS-CSB- 494, 2012

Public Open Space

- Former sewage-filled subsidence basins have been converted into vast wetlands, cleaning 80,000 tons of reclaimed water each day.
- Visitors are brought closer to an informative natural experience by boats and broad walkways.
- Wildlife-friendly spaces have been created in several sensitive places. (Biennal, An, Y., et al., 2014)

Fig. (52) Spectacular Public Spaces,
Source: LPS-CSB- 494, 2012



Public Recreational areas

- Tangshan residents and visitors can enjoy a variety of leisure possibilities at the park (LPS-CSB- 494, 2012)
- The hill, a central island, botanical garden, and main plaza are among the park's recreational spaces.
 - People are drawn to the water by boat docks and broad boardwalks around the lakeshores.

Fig. (53) Variety of Public leisure areas,
Source: LPS-CSB- 494, 2012



Impressive Features

To stabilize the banks, dormant willow poles (huge willow cuttings) were planted along the lakeshore. The willow stakes sprouted as predicted the following spring, demonstrating the success of the strategy. Willows will provide shade and habitat as well as maintaining the banks in the long run. (LPS-CSB- 494, 2012)

The 4,500,000 m3 of waste was gathered and turned into a green hill with native trees, bushes, and wildflowers, offering a panoramic perspective of the city and a heartfelt experience of nature's power. (Biennal, An, Y., et al., 2014)



Fig. (54) Green Hill, formerly Garbage hill
Source: LPS-CSB- 494, 2012; Biennal, An, Y., et al., 2014

Landscaping Important features



Fig. (55) Bird's Eye View: from South to North: Both "Cedars and grassland" Peninsular and "Inviting-the-Moon" Island were constructed with coal ash.
Source: Biennal, An, Y., et al., 2014

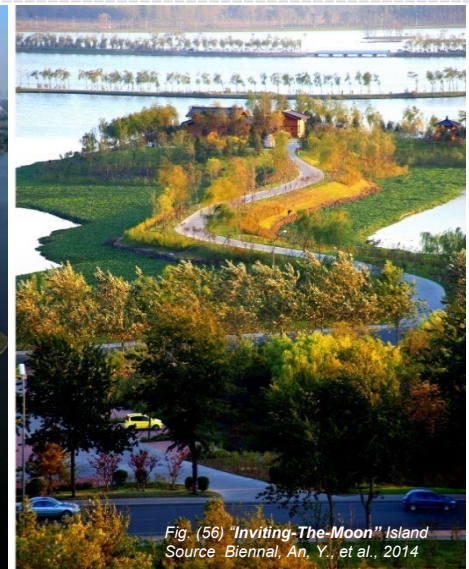


Fig. (56) "Inviting-The-Moon" Island
Source: Biennal, An, Y., et al., 2014

- "Inviting-The-Moon" is a vantage point for enjoying the lake's fresh breeze and stunning views, regenerated from conserved tree islands.
- Traditional Chinese timber shelters were created to provide a secure and energy-efficient shelter. Promoting the enjoyment of regular walks and engagement with various wetland flora and fauna through routing the boardwalks around shady wetland ponds. Lower environmental impacts of carefully erected wooden boardwalks which are more durable in the event of ground subsidence. (Biennal, An, Y., et al., 2014)

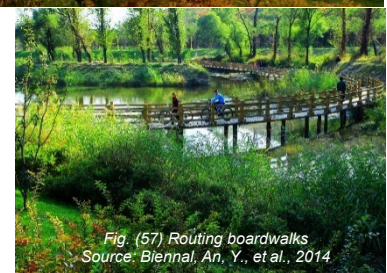


Fig. (57) Routing boardwalks
Source: Biennal, An, Y., et al., 2014

Only within three years, a 630-hectare wasteland has been turned into northeastern China's largest urban central park, greatly enhancing Tangshan's environmental quality, offering valuable public open space, and providing crucial home for urban fauna. (Biennal, An, Y., et al., 2014)

From Abandoned Urban Brownfield

2006



Quality achieved:

To Cherished Public Open Space



Fig. (58) Quality Achieved: The environmental quality of Tangshan City was improved, a public open space was created, and habitats for urban wildlife were rehabilitated, Source: Biennal, An, Y., et al., 2014; ULI Americas, 2013

- Carbon sink • Climate regulation • Providing animal habitat • Biodiversity protection • Water saving
- Waste gas treatment • Waste recycling • Providing recreation • Commercial taxation • Enhancing land value

BEFORE

AFTER

Achievement



Fig. (59) Formerly Coal mining site,



Fig. (60) Currently largest urban central park in northeastern China

Source: LPS-CSB- 494, 2012

- Tangshan's extreme minimum temperature has climbed 3-4°C after the establishment of Nanhu Central Park, while its extreme maximum temperature has fallen 3-4°C.
- Tangshan city's urban green coverage has increased from 41.57% to 44%.
- Currently more than 100 different species of wild birds exists.
- The land value in the Nanhu area has risen by at minimum 16 billion dollars.
- Over 100.000 daily visitors of the Central Park during the holidays. (Biennal, An, Y., et al., 2014)

Water

A succession of minor water features, as well as two lakes, provide visual and recreational appeal. These lakes recharge without potable water and fill old subsidence basins. After being released by a water treatment facility into a series of artificial wetlands, approximately 80,000 m³ of reclaimed water is received daily by the south lake. The north lake is replenished daily with 20,000 m³ of groundwater from the park's coal mining location to the north. The two lakes provide irrigation water for the surrounding area. (LPS-CSB- 494, 2012)

Flora

- The park contains about 623,144 trees and shrubs representing about 100 different species, offering a variety of wildlife habitats such as woodland, bosque, grassland, and marsh.
- Comprised of about 45 different tree species and 42 different shrub species.
- The park's trees can sequester 2,828 metric tons (6,233,946 lbs) of CO₂, with evergreen trees accounting for 158 metric tons (348,454 lbs) and deciduous trees accounting for 2,670 metric tons (5,885,492 lbs). (Li, M., et al., 2012)



Fig. (61) Observed Bird species, Source: LPS-CSB- 494, 2012

Fauna inventory

- In Nanhu Park, 6 fish species, 4 reptile species, 3 amphibian species, 2 mammal species, and 81 bird species were discovered.
- 81 bird species were attracted by the creation of woodland, bosque, grassland, and wetland habitats.
- From observed wildlife, **7 species**, the *whooper swan*, *northern harrier*, *common buzzard*, *common kestrel*, *red-footed falcon*, *Eurasian scops owl*, and *long-eared owl*, are national second-class protected wildlife, while **81 species** have important economic and research significance. (Li, M., et al., 2012)

Area Re-naturalized

- The picturesque peninsula on the north side of the southern lake, as well as the islands in the center of each lake, are created with reclaimed coal ash.
- The lakefront is stabilized with a gabion embankment and 133,820 dead tree trunks and branches piled together. (LPS-CSB- 494, 2012)

Environmental Strategies:

- Recycled Water as Supplement
- Existing fishpond and subsidence areas are the base for wetland and water system creation
- Native Plant Design and Existing Plant Reservation
- Reduce Emissions and Resource Consumption by Using Wooden Architecture

Environmental & Economic Strategies:

- Industrial Waste Treatment and Utilization
- Trash-Filled Hill

Social Strategies

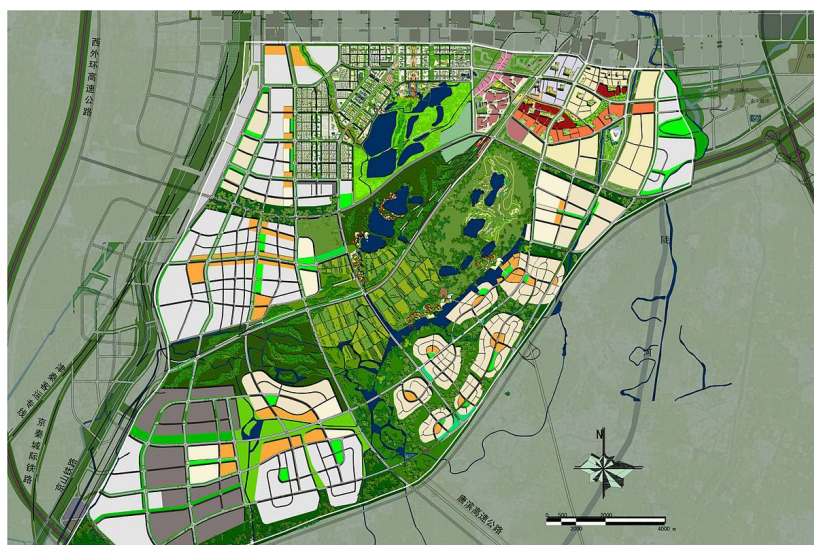
- Provide Public Recreation with Green Space

Environmental & Social Strategies

- Central Park connection through Green Corridor

Economic Strategies

- Cost Saving
- Business Taxes
- Increase the Land Value



(Yang, Y., et al., 2016)

Fig. (62) Park's Master plan, Source: Wikimedia.org, Date accessed: August 6, 2021

SOCIAL

- A 15-minute walking distance park access for adjacent 10,000 residents.

ECONOMIC

- **Material costs saving** of \$47.2 million through utilization of 6 million m³ of coal ash in production of bricks and foundations for construction of the park.
- **Construction costs saving** of \$369,000 through reusing 133,820 dead tree trunks to make an embankment construction for lakefront erosion prevention.
- Earns \$157,300 in annual revenue through recreative and facility leasing fees.

(LPS-CSB- 494, 2012)

Strategies

Socio/Economic Benefits

4.2.3 Case study's Environmental Analysis Summary according to proposed indicators

Table (7) Tangshan Nanhu Central Park's Environmental Analysis Summary, Source: Author, from Li, M., et al., 2012

| Category | Indicator | Sub-Indicators /Description | Type | Output |
|-----------------------|---------------------------------|--|--------------|--|
| Environmental Aspects | Climatic Aspects | Air Quality - Air quality: Improvement in air quality due to increased vegetation cover | Quantitative | <ul style="list-style-type: none"> Sequesters an estimated 2,800 metric tons (6.2 million lbs) of CO₂ annually in the trees of the park, equivalent to removing 555 passenger vehicles from the road each year. |
| | | Urban Micro-Climate - Heat Island Effect: % of decrease in Heat Island Effect due to increased vegetation cover and water bodies | Quantitative | |
| | | Carbon Footprint - Carbon Footprint: amount of carbon dioxide and other GHG emissions associated with the wetland project compared to conventional treatment plant | Quantitative | |
| | Sustainability | Energy - Construction Energy Conservation: % of energy conserved during construction stage compared to conventional treatment plant - Operation Energy conservation: % of operational electrical energy conserved compared to conventional treatment operations measured over a specific temporal scale | Quantitative | No Data Available |
| | | Materials - Recycled Materials: % of materials that is recycled or acquired from onsite materials - Hazardous Materials: % of hazardous materials and chemicals employed in water treatment process compared to conventional treatment processes | Quantitative | <ul style="list-style-type: none"> Saved \$47.2 million in material costs by reusing 6 million cubic meters of coal ash to produce foundations and bricks used in park construction. Saved \$369,000 in construction costs by recycling 133,820 trunks of dead trees to form an embankment structure to prevent erosion along the lakeshore. |
| | | Solid/Liquid Wastes - Quality/ Quantity of wastes: % of waste materials discharged during the treatment process | Quantitative | 450 metric tons of rubbish in Nanhu area were reclaimed and used to create a 50-meter-high hill, offering 130,000 square meters of green space. |
| | | Soil - Quality/ Quantity of soil creation, preservation & restoration: % of fertile or restored soils | Quantitative | No Data Available |
| | Biodiversity: Habitat Diversity | Flora (Vegetation) - Number of Fauna and Flora species introduced into the habitat | Quantitative | More than 620,000 trees and shrubs of about 100 species are planted in the park, creating various wildlife habitats including woodland, bosque, grassland, and wetland. |
| | | Fauna - Number of Fauna and Flora species introduced into the habitat | Quantitative | Provides habitats for 6 fish, 4 reptile, 3 amphibian, 2 mammal, and 81 bird species observed on the site. Of these, 7 are nationally protected wildlife species. |
| | Water | Water Reused - Water Reused: % of water reused or reintroduced to the irrigation system. | Quantitative | Reduces potable water consumption by 29,200,000 cubic meters (7.7 billion gallons) annually, equivalent to 11,680 Olympic-sized swimming pools, by importing reclaimed water from a nearby sewage treatment plant. The reclaimed water is further treated in a series of constructed wetlands and used for water body recharge and irrigation in the park, saving about \$15.4 million per year. |
| | | Water Quality - Water quality: % of pathogens removed through the constructed wetland | Quantitative | |

4.2.4 Relevance to Case study, 10th of Ramadan Park

1- Design Development

- Low-Carbon, Low-Impact, Low-Cost design Techniques
- Waste plant materials recycled to stabilize water banks

2- Material:

Use of existing material to create a high hill that offers green space providing scenic views and various recreational opportunities

3- Waste Management:

A waste gas collection system to prevent emission into atmosphere.

4- Public Open Space

- Transforming sewage basins into attractive water features
- Specific designed wildlife areas
- Bringing visitors, through boardwalks, closer to an educational natural experience.

5- Public Recreational areas

- Providing numerous recreational opportunities to residents and visitors.
- Engaging visitors with the water through designed pathways
- Various recreational spaces for vibrant experience

6- Impressive Features

- Installing vegetation to stabilize banks in addition to providing shade, habitat and aesthetic values
- Stabilized hill as a landform covered with native trees, shrubs, and wildflowers.

7- Landscaping Important features

- Designing a lookout point to enjoy beautiful scenery with traditional structures
- Designing routing shaded pathways to increases interactions with diverse wetland plants and wildlife

8- Water

- Series of water features, offer scenic and recreational value
- Water features recharged with treated water instead of potable water.
- Treated water are the source for landscape irrigation.

9- Flora

- Diversity of vegetation species to create various wildlife habitats
- Planting more than 45 tree species and 42 shrub species

10- Fauna inventory

Offering various appropriate habitats which enrich the animal species

11- Strategies

- **Environmental Strategies:** Build Water System and Wetland Based on Existent resources, The existent plant Reservation and Native Plant Design, Reduce Emission and Resources Consumption
- **Environmental & Economic Strategies:** Waste Treatment and utilization and Trash-filled Mountain
- **Social Strategies:** Create Green Space for Public Recreation
- **Environmental & Social Strategies:** Connections through Green Corridor
- **Economic Strategies:** Cost Saving, Business Taxes, Enhance the Land Value

12- Socio/Economic Benefits

SOCIAL: Provides Park access for the nearby residents within a 15-minute walking distance.

ECONOMIC:

- Saving of material cost through reuse of available site materials in park construction.
- Saving of construction costs by recycling vegetation wastes in structures to prevent erosion.
- Generating revenue from recreational and facility rental fees

4.3 Tianjin Qiaoyuan Park: The Adaptation Palettes

4.3.1 Introduction:

Location: Tianjin, China, 2008

Climate Zone: Cold semi-arid

Scale: Medium-scale Park; 0.22 km²

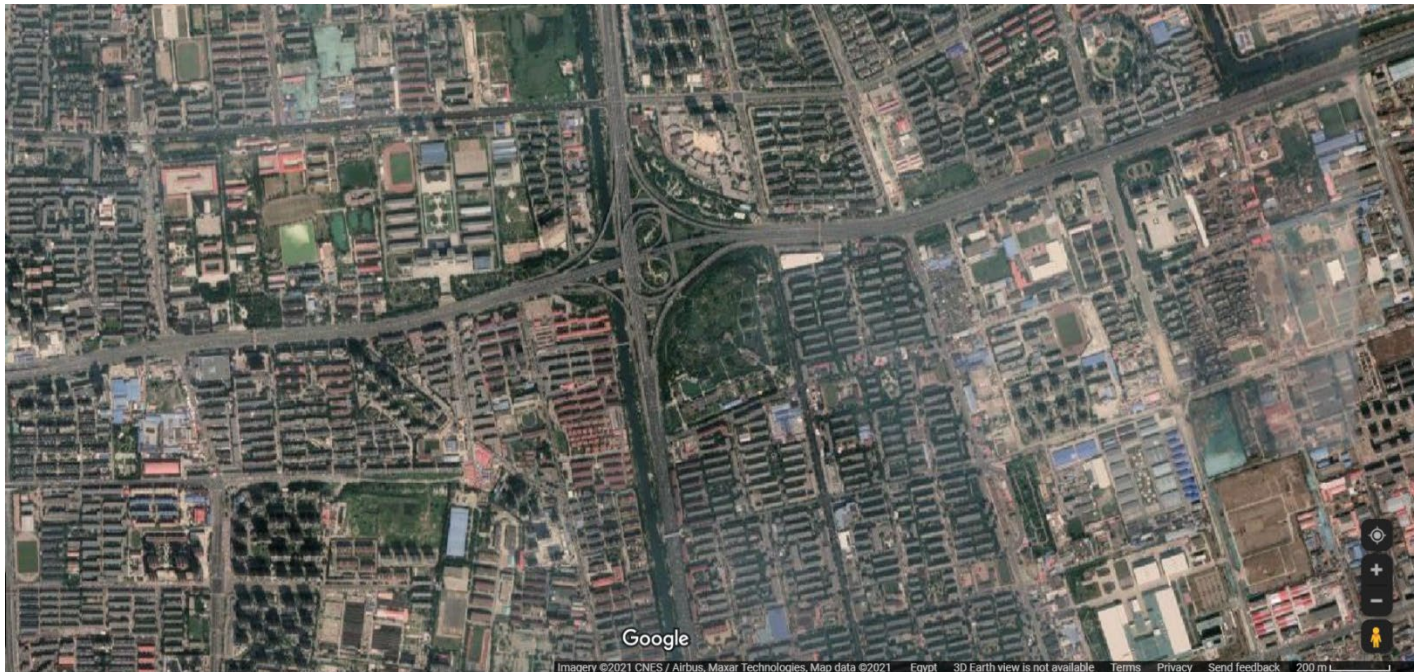


Fig. (63) Tianjin Qiaoyuan Site Location, Source: Google Map, Date accessed: Sep. 1, 2021



Fig. (64) Tianjin Qiaoyuan Wetland Park's Location, Source: Google Map, edited by Author, Date accessed: Sep. 1, 2021

4.3.2 Analysis:

Case Study 3 Tianjin Qiaoyuan Park: The Adaptation Palettes

| | |
|------------------------------------|---|
| Location | Tianjin, China |
| Area | 218,530 m ² , 0.22 km ² , 54 acres (Medium-scale Parks) |
| Designer | Turenscape |
| Project Type | Park/Open space Wetland creation/restoration |
| Climate Zone | Cold semi-arid |
| Former Land Use | Brownfield, Previously a military shooting range and then a garbage dump, surrounded by slums and highways. |
| Cost US\$ | 14.1million |
| Completion | 2008 |
| Site and Climatic Condition | Polluted urban stormwater runoff flowed to and ponded on the site, complicating drainage due to many linkages between surface and groundwater. The soil was extremely polluted, saline, and alkaline, making it a difficult environment for plants to thrive in. This coastal region in the Bohai Gulf used to be rich in wetlands and salt marshes, but decades of urban expansion have destroyed most of them. (LPS-CSB- 425, 2011) |
| Project's Concept | Regenerative Design through natural processes, Preservation & Restoration, Low-Maintenance Urban Park The general design objective for this project is to build a park that can provide a variety of natural services to the city and adjacent urban residents, such as controlling and purifying urban storm water, enhancing saline-alkali soil via natural processes, restoring the surrounding landscape with low-maintenance native flora, and promoting environmental awareness and education about indigenous landscapes and natural ecosystems, as well as storm water management, and soil enhancement. (Landezine, 2011) |

Introduction

Natural plant adaptability and succession were introduced through regenerative design, resulting in the transformation of a 54-acre waste dump in Tianjin, China, into a low-maintenance urban park. The 21 "bubbles" (wet and dry cavities) manage off-site urban runoff, enhance saline-alkali soil through natural methods, and allowing lush patches of native plant to grow periodically, producing a distinctive, "messy" visual experience. This eco-friendly design reveals how an irregular, constantly evolving landscape may result in a sustainable park with high visual appeal and low care requirements. (LPS-CSB- 425, 2011)



Fig. (65) Site condition, Source: Turenscape, 2009

Design Zones

21 pond cavities of varying sizes and depths were carved out, with diameters ranging from 10-40m and depths ranging from 1.1-5m, including some cavities under ground level and others above on dunes. The site's urban stormwater runoff is trapped in deep ponds, where pollutants can deposit. The resultant "bubbles" are a combination of water-ponds, wetlands, periodic ponds, and dry cavities that are supplied by rain and groundwater and have seasonal water levels. (LPS-CSB- 425, 2011)



Fig. (66) Pond Cavities, Source: Turenscape, 2009

Fig. (67) Pond Cavities design Zones, Source: Cyclifier, 2013





Fig. (68) Bird-eye view of the park, Source: World-Architects, 2013

Inspired by the adaptable vegetation types that populate the terrain, a basic landscape design technique was developed: Natural functions would be reintroduced, and permitting dynamic processes of adaptation and succession, rather than attempting to return the place to some prior natural form. The wash and filtration impacts of seasonal rain enhance soils in the dry cavities, while deeper ponds catch stormwater runoff and nutrients. During the earthwork, garbage was removed from the site. Initially, seeds of a mixture of ground cover and wetland plants were sown, while other natural species were permitted to take root wherever needed. Seasonal fluctuations in the water table and PH values cause dense areas of plants to emerge, resulting in a low maintenance, "messy" natural environment with a distinct appearance. Visitors may explore the site by walking through the palettes on red-colored asphalt tracks with interpretative signage and extending wooden platforms into the cavities and ponds. (LPS-CSB- 425, 2011)

Design Development

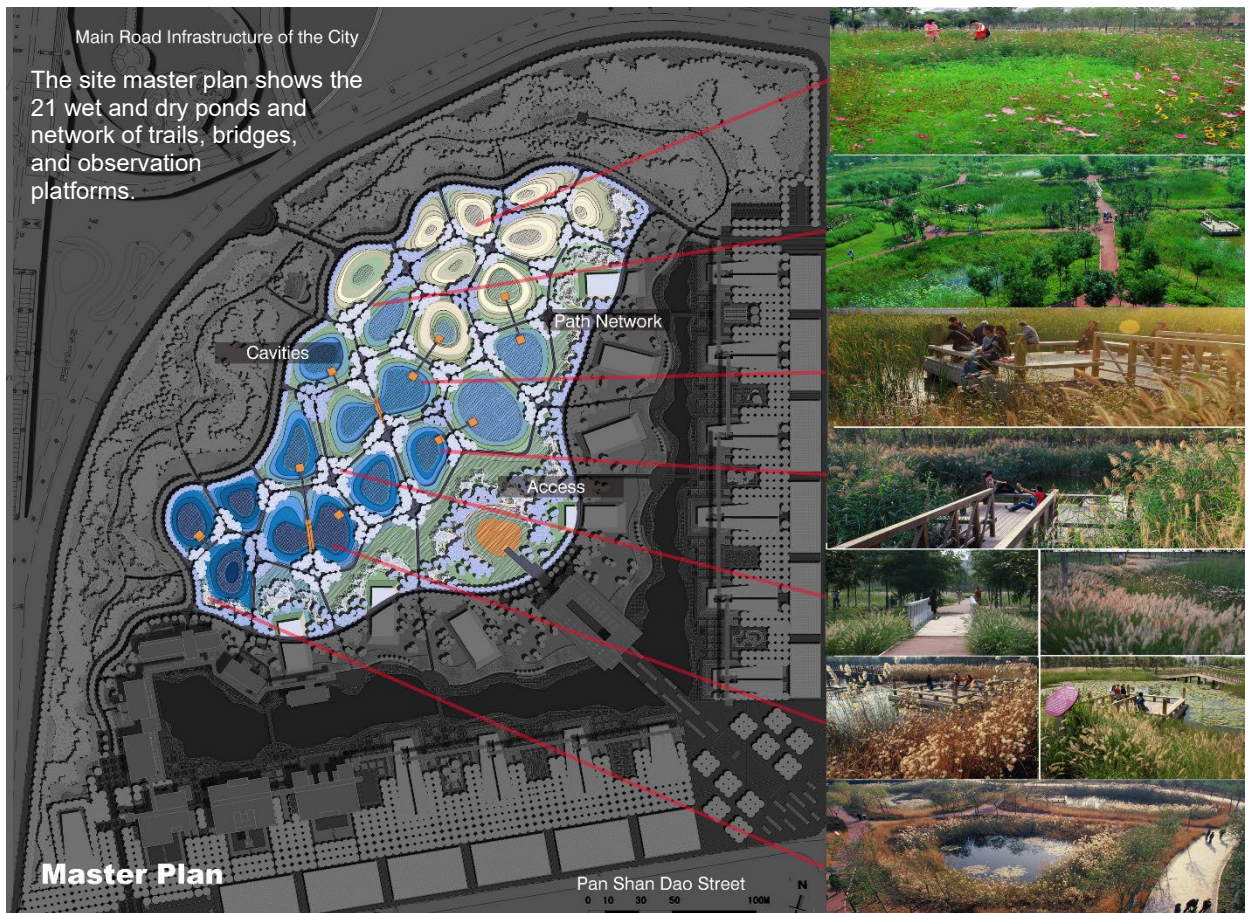


Fig. (69) Park's Site Plan for the various ponds, Source: Turenscape, 2009

Design: The adaptive palettes

The site's natural functions had been damaged, and a successful park was defined by the integration of ecosystem services such as supplying, regulating, supporting, and cultural services into the design. The goal was to use the vernacular landscape to renew biological processes, minimise soil and water pollution, and allow the site to adapt and evolve naturally. The community's need for a visually appealing open area for local activities was also critical to the design's success: (World-Architects, 2013)

a) Habitat establishment: The initial phase was to regrade the land so that storm water could be collected, stored, and treated in varying depths ponds. To generate topography, inert worksite garbage was recycled as fill material. Each of the 21 ponds has a diameter of 20-40 metres and varying depths. Each pond's relative moisture levels and pH generate microhabitats ranging from wetlands to wet meadows and grasslands.

(b) Plant community design: The plant community began as a seed. The seed mixing were created particularly for each environment to ensure that a biologically varied plant population thrived. Instead of maintaining a precise planting pattern, the design's dynamic, self-evolving, and adaptable character allows species to move and alter over time. Wind and bird dispersal help indigenous species to become a part of the landscape. While the site treats and balances the saline-alkaline soil, communities of plant will go through multiple stages of succession. The cycling of plants and nutrients begins a natural cycle of growth, pollination, reproduction, and decomposition by enabling the plant population to alter throughout the year.

(c) Cultural services: The adaptable palettes are a living system, and the walkways provide a network of connections for visitors. Willow trees surround the ponds, and platforms and bridges are delicately built to immerse visitors in a panorama of natural grasses and wildflowers. At each pond, interpretive signage depicting each plant community explains natural processes such as the water cycle, ecological advantages, and key plant species. The park is transformed into a recreational environment, inspiring a sense of community responsibility and ownership.



Design Development

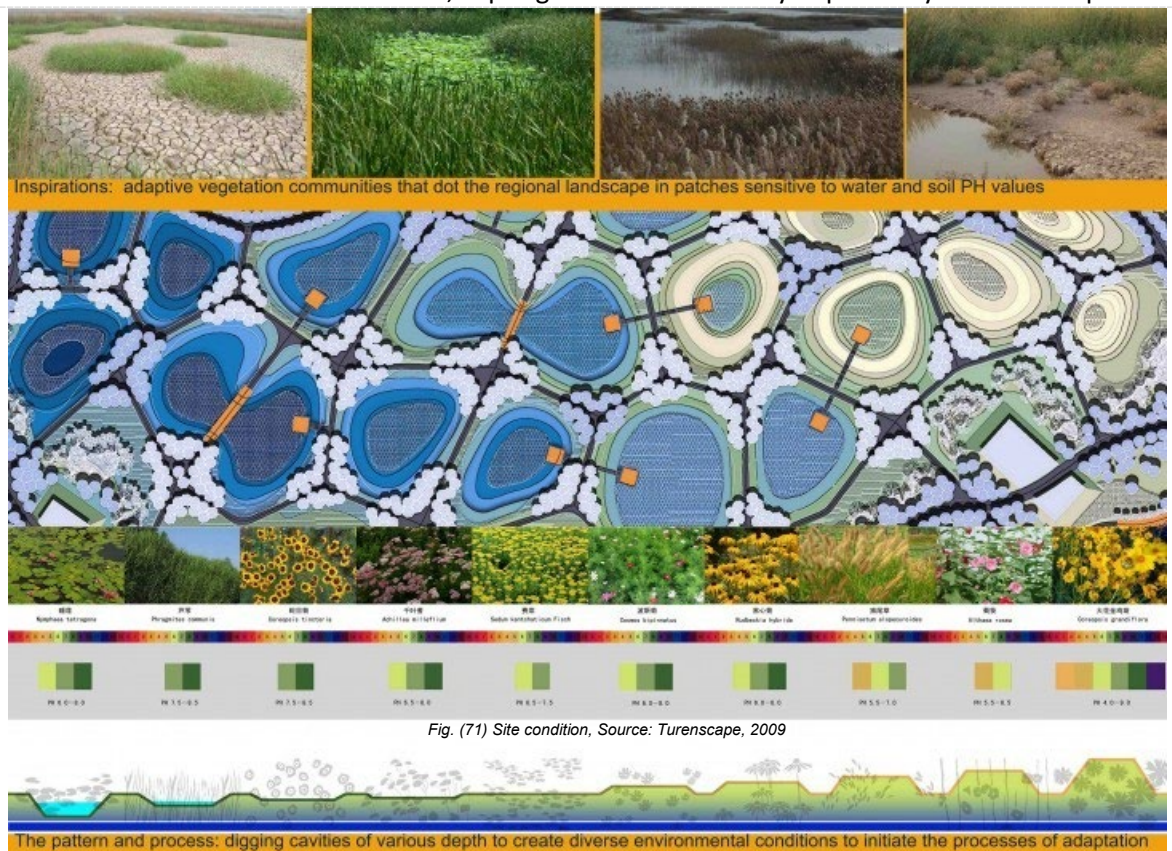


Fig. (71) Site condition, Source: Turenscape, 2009

"Let Nature Work" is a design idea influenced by regional landscapes that depicts cavities, water levels, and pH ranges creating various environmental conditions that launch the adaptation process. (LPS-CSB-425, 2011, Turenscape, 2009)

The viewing platforms and bridges were built with over 85 cubic metres of recycled railroad ties. Soil, plants, and limestone were all supplied locally. (LPS-CSB- 425, 2011)

Material

Public Open Space



Fig. (72) Public open spaces, Source: Turenscape, 2009, Ma, W., 2014
The project added 54 acres to Tianjin's public open space, featuring wetland area, highland space, and hydrophilic space.



Fig. (73) Impressive Public open spaces, Source: Turenscape, 2009

- Visitors may relax on the wooden platforms, which are bordered by wetlands.
- The network is intersected with red asphalt walkways that provide visitors with a variety of exploration options.
- Signage outlines the park's species and natural processes, which visitors may learn about during their visit. (Ma, W., MIT, 2014; LPS-CSB- 425, 2011)

Public Recreational areas

- Almost each pond includes an observation platform as well as interpretive signage explaining ecological patterns, processes, and indigenous species. Visitors may discover simple natural science while observing and becoming closer to nature. (LPS-CSB- 425, 2011)

- *Left:* Visitors to the park enjoy the wetland nature and tranquilly of shallow ponds.
- *Right:* During Autumn: Visitors can relax at one deep-water pond.



Fig. (74) Shallow Water Ponds, Source: Turenscape, 2009



Fig. (75) Deep water pond in Autumn, Source: Turenscape, 2009

Impressive Features

- A landscape's distinctive aspect is the interconnecting pedestrian walkways that ring each of the ponds. However, compared to a strategically placed paths site, this scattered pedestrian system makes circulating, privacy, and community activities difficult.
- An observation deck available at almost every pond.
- The Bridgepark is known as Qiaoyuan ('qiao' means bridge and 'yuan' means garden). The name refers to one of the few remaining tracts of open spaces in the area, as well as its proximity to the Weiguo highway junction. The community's southern and eastern faces provide a strong future link to the area.

(LPS-CSB- 425, 2011; World-Architects, 2013)



Fig. (76) Interconnected pedestrian paths and bridges, Source: World-Architects, 2013



Fig. (77) Observation Decks, Source: Turenscape, 2009



Fig. (78) Various Plants, Source: World-Architects, 2013



Fig. (79) Impressive bridges, Source: Landezine, 2011



Fig. (80) Plant communities, Source: Landezine, 2011



Fig. (81) Paths & water, Source: Turenscape, 2009



Fig. (82) Bridges & Water, Source: INHabitat, 2013

Landscaping Important features

- Along the border of water collecting cavities, several vegetation populations emerge, revealing differences in water level and soil pH.
- The succession of wet, dry, and seasonal ponds manage runoff, enhance soils, and allow rich areas of natural plant to grow seasonally, resulting in a distinct, "messy" visual experience. In the fall, flora thrives near deep water ponds.
- Strong landscape arose by implementing a new ecological plan and recognizing the surrounding community's requirements.
- China's regenerated ecological park introduced a new aesthetic that adheres to environmental principles and enhanced feeling of worldwide ecological consciousness.
- This technique suggests a promising future for ecological urbanism in landscape design.
- To trigger nature's ecosystem services, the designers honored the vernacular environment and its natural processes. This strategy provides endless ecological benefits while also revealing the community's and city's historic vernacular landscape.

(LPS-CSB- 425, 2011; World-Architects, 2013)



Quality achieved:

- Old vacant site is transformed into a new ecological park through basic ecological regenerative design.
- Within two years, ecological services such as storm water management, soil and water enhancement, biodiversity preservation, aesthetics, stewardship and recreation completely altered the site.
- Field data show that it improves soil alkalinity in dry ponds and water quality in wet ponds. The pH of the soil has gone from 7.7 to roughly 7.2, while the pH of the water has declined from 7.4 to 7 or less.
- It is a successful park with a changing scenery throughout the year, is regularly accessed by the public, and requires minimal care.
- The project contributes to the current new landscape aesthetics, which are characterized by a continual changing process.
- Unmaintained shapes, spontaneous biodiversity, and nature's "messiness" continue to exist, allowing plants to flourish and reveal their true beauty to enhance the landscape.
- The ecologically oriented Adaptation Palettes has evolved into a vital and extraordinary resource for the Tianjin community.
- The site's trees and plants are anticipated to sequester 539 tons of carbon, service worth around \$7,200.

(World-Architects, 2013; Divisare, 2012; Rottle, N., & Lacson, 2011)

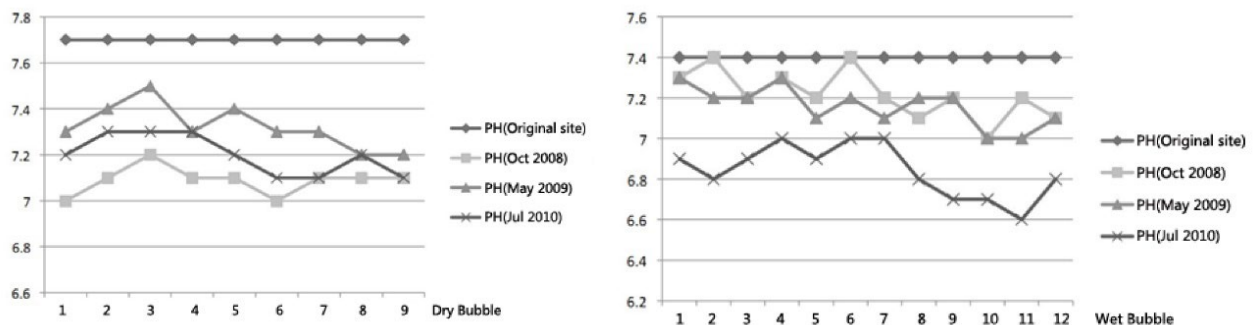


Fig. (88) Bubble's Soil Sample for wet and dry ponds, Source: Rottle, N., & Lacson, 2011

BEFORE



AFTER



Achievement

Fig. (89) Former site, garbage dump, Source: LPS-CSB- 425, 2011

The location had been a waste dump and old military shooting range, as well as a stormwater drainage basin bordered by highways and slums (LPS-CSB- 425, 2011)

Fig. (90) Shallow & seasonal water ponds, Source: Turenscape, 2009

The pond cavities, walking trails, and patchy terrain with varied plant groups are visible in this summer bird's-eye view of the park

During the rainy season, and owing to the shallow subterranean water, some cavities transform into water ponds, others into wetlands, yet others into seasonal pools, while others remain dry cavities.

Water

The dry cavities' saline-alkali soil improves with the seasons' rain wash and filtration, while nutrients accumulate in the deeper ponds that capture storm water runoff.

(Divisare, 2012)

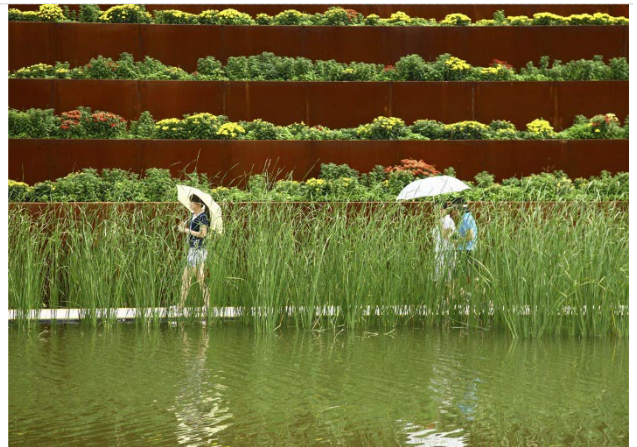


Fig. (91) Pedestrian pathways through various water ponds, Source: World-Architects, 2013

Flora

- Improved the site's habitat value by increasing the number of herbaceous plants from 5 (four types of xerophytes and one type of aquatic plant) to 96 various species after two years (85 dry plants species and 11 aquatic plants species).
- The tree species number has grown from two to fifty.
- Perennials account for 40% of the park's plantings, with 58 species, and woody plants account for 34% of park's plantings, which come in 50 species. More than 99 % are native species.
- Plant communities were allowed to grow and evolve over time, with seasonal fluctuations in water level and pH resulting in spots of distinct vegetation forming.
- The reed population at the water's edge dominates shallow water pond

(Rottle, N., & Lacson, 2011; LPS-CSB- 425, 2011)



Fig. (92) Diverse plant Communities, Source: Turenscape, 2009

Fauna inventory

- Fauna species has grown to six.
 - There have been reports of ducks, geese, foxes, hedgehogs, rats and weasels on the park's site.
- (Rottle, N., & Lacson, 2011)

Area Re-naturalized

- The design strategy of restoring natural functions while allowing dynamic processes of adaptation and succession to take place resulted in a diversified ecosystem with minimum management requirements.
- Design process comprised crucial procedures of precise planning and plant selection, species experimentation, progress monitoring during construction phase, as plants developed, and accordingly modifying the design to reach the optimal performance.

(LPS-CSB- 425, 2011)



Fig. (93) Minimum Management Ponds, Source: Turenscape, 2009

Environmental Strategies:

- Integrating the Rain Harvesting System with Topographical Design
- Field Trash reuse
- Use Dynamic Seeding to Select Adaptability Plants
- Conservation of Biodiversity
- Revive the Regional Landscape's Characteristics

Strategies

Social Strategies

- System Design for Recreation
- Promote Environmental Aesthetics
- Ecological Interpretation Design

Economic Strategies

- Low Cost

(Yang, Y., et al., 2016)

SOCIAL:

- Field measurements show that the noise level in the park drops from 70dB outdoors to 50dB inside.
- Expands access to green space for the 20,000 surrounding inhabitants, with under 15-minutes-walk to the park. In addition to a total of 26 bus lines that service the park.
- An important destination, with 350,000 visitors annually, majority are from neighboring areas. Over half of the visitors are seniors, while 40% are youngsters.
- Offers educational experience to around 500 kids of local schools, with more pupils engaging in summer vacation programs and general activities at nearby Bridge Museum.
- Increases Park visitors' ecological understanding and consciousness, with 83 % of those interviewed approving the park's ecological approach.

Socio/Economic Benefits

(Rottle, N., & Lacson, 2011)

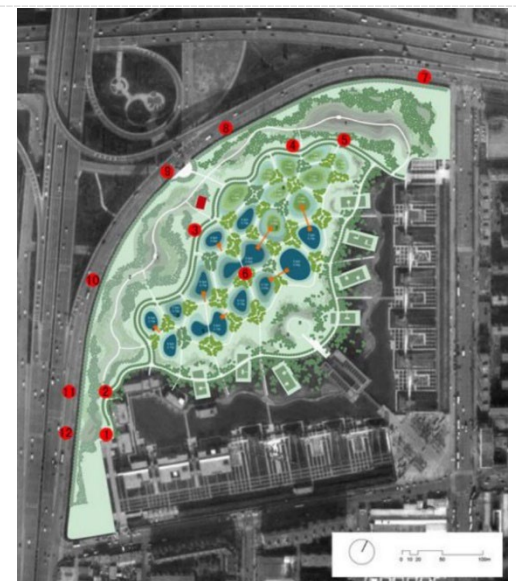


Fig. (94) Noise reading points, Source: Rottle, N., & Lacson, 2011

ECONOMIC:

- Minimal maintenance "bubbles" (wet and dry ponds) save over \$19,000 in annual maintenance costs when compared to the average cost of weeding, trimming, irrigating, and fertilizing of a standard park.
- Reusing 84.5 cubic meters of obsolete railroad ties in the building of the observation platforms and bridges saved around \$25,500 in timber expenses.
- Water quality is maintained by the ponds' design and the employment of native vegetation, which necessitates just a limited amount of water treatment chemicals. When compared to the cost of water treatment chemicals in a regular park, this saves over \$5,000 per year.

(Rottle, N., & Lacson, 2011)

4.3.3 Case study's Environmental Analysis Summary according to proposed indicators

Table (8) Tianjin Qiaoyuan Park's Environmental Analysis Summary, Source: Author, from Rottle, N., & Lacson, 2011

| Category | Indicator | Sub-Indicators /Description | Type | Output |
|-----------------------|------------------|--|--------------|--|
| Environmental Aspects | Climatic Aspects | Air Quality - Air quality: Improvement in air quality due to increased vegetation cover | Quantitative | Sequesters an estimated 539 tons of carbon in the trees and plants on the site, a service valued at approximately \$7,200. |
| | | Urban Micro-Climate - Heat Island Effect: % of decrease in Heat Island Effect due to increased vegetation cover and water bodies | Quantitative | No Data Available |
| | | Carbon Footprint - Carbon Footprint: amount of carbon dioxide and other GHG emissions associated with the wetland project compared to conventional treatment plant | Quantitative | The carbon fixation of reed wetland is 13.32t/ha, therefore it is estimated that 12tons of carbon are sequestered in 8,997m2 reed. |
| | Sustainability | Energy - Construction Energy Conservation: % of energy conserved during construction stage compared to conventional treatment plant - Operation Energy conservation: % of operational electrical energy conserved compared to conventional treatment operations measured over a specific temporal scale | Quantitative | No Data Available |
| | | Materials - Recycled Materials: % of materials that is recycled or acquired from onsite materials - Hazardous Materials: % of hazardous materials and chemicals employed in water treatment process compared to conventional treatment processes | Quantitative | Saved approximately \$25,500 in lumber costs by reusing 84.5 cubic meters of old railroad ties in the construction of the observation platforms and bridges. |
| | | Solid/ Liquid Wastes - Quality/ Quantity of soil creation, preservation & restoration: % of fertile or restored soils | Quantitative | During construction, waste was minimized and recycled wherever possible. Inert onsite waste reclaimed as fill material to create topography |
| | | Soil - Quality/ Quantity of project discharges into soil: % of wastes discharged into soil | Quantitative | Improves soil alkalinity in the dry ponds and water quality in the wet ponds as evidenced by field measurements. Soil pH dropped from 7.7 and now fluctuates around 7.2, and water pH levels dropped from 7.4. to 7 or less. |
| | | Flora (Vegetation) - Number of Fauna and Flora species introduced into the habitat | Quantitative | <ul style="list-style-type: none"> Increased the habitat value of the site, with the number of herbaceous plant greatly increasing, from 5 to 96 species Tree species increased from 2 to 50. |
| | | Fauna - Number of Fauna and Flora species introduced into the habitat | Quantitative | Species increased to 6, accounting for ducks, geese, foxes, hedgehogs, rats and weasels. |
| | Water | Water Reused - Water Reused: % of water reused or reintroduced to the irrigation system. | Quantitative | Water fluctuates in different space and time, and it nurtures different species and purify the saline soil |
| | | Water Quality - Water quality: % of pathogens removed through the constructed wetland | Quantitative | |

4.3.4 Relevance to Case study, 10th of Ramadan Park

1- Material

- Reuse of materials in the construction of the observation platforms and bridges.
- Regional sourcing of soil, plants, and constructing materials

2- Public Open Space

- Increasing public open space through various spaces and zones
- Designing of wooden platforms surrounded by wetlands for various uses
- Multiple choices of exploration network for visitors through different path materials
- Descriptive signage of species and ecological process of the park; educational experience

3- Public Recreational areas

- Observation platforms and interpretive signs describes natural patterns, processes, and native species.
- Providing opportunities for visitors to observe, get closer to nature and to learn basic natural science.
- Diverse structures of shallow and deep ponds create distinct experiences and serenity in all seasons

4- Impressive Features

- Interconnected pedestrian path network creates unique circulation, privacy, and activity experience
- Adjacency to the community ensures a strong connection to the neighborhood in the future.

5- Landscaping Important features

- Diversity of plant communities
- Rich patches of native vegetation creating a unique seasonally “messy” aesthetic experience.
- Understanding the needs of surrounding community and employing a new environmental strategy
- Aesthetic ecological park that adheres to environmental ethics with sense of ecological awareness
- Strategy of bright perspective for ecological urbanism in design
- Respecting the vernacular landscape and its natural processes to initiate nature’s ecosystem services

6- Water

- Diverse seasonal activities during raining season, cavities turn into water ponds, wetland, ... etc.
- Improvement of soil in raining seasons, while nutrients deposit in ponds catching storm water runoff

7- Flora

- Increased the habitat value of the site through increasing vegetation species of mainly native species
- Allowing plant communities to evolve and adapt over time

8- Fauna inventory

- Increasing animal species by offering various appropriate habitats

9- Area Re-naturalized

- Reestablish natural functions and dynamic processes of adaptation and succession
- Creating diverse habitats requiring minimal management.
- Careful planning and plant selection, species trialing, progress monitoring for best performance

10- Socio/Economic Benefits

SOCIAL:

- Improving access to green space for the nearby residents within 15 minutes’ walk
- Serving various age groups of visitors through distinct activities for seniors, adults and children
- Provides educational opportunities for nearby schools and summer activities vacation programs
- Improves ecological awareness and environmental consciousness of park visitors

ECONOMIC:

- Saving of maintenance cost of weeding, pruning, irrigating, and fertilizing through low maintenance “bubbles” (wet and dry ponds)
- Saving of water treatment chemicals cost through the use of native plants that maintain water quality and requiring only small applications of water treatment chemicals.

4.4 Shanghai Houtan Park

4.4.1 Introduction:

Location: Shanghai, China, 2010

Climate Zone: Humid subtropical

Scale: Large-scale Park; 0.14 km²



Fig. (95) Shanghai Houtan Site Location, Source: Google Map, Date accessed: Sep. 1, 2021



Fig. (96) Shanghai Houtan Wetland Park's Location, Source: Google Map, edited by Author, Date accessed: Sep. 1, 2021

4.4.2 Analysis:

Case Study 4 Shanghai Houtan Park

| | |
|--------------------------------------|--|
| Location | Shanghai, China |
| Area | 139,616.55 m ² , 0.14 km ² , 34.5 acres (Medium-scale Parks) |
| Designer | Turenscape |
| Project Type | Park/Open space Waterfront redevelopment Wetland creation/restoration |
| Climate Zone | Humid subtropical |
| Former Land Use | Brownfield A landfill and storage yard, a former industrial site |
| Cost US\$ Completed | \$15.7 million 2010 |
| Challenges and Site Condition | <p>The restoration of the deteriorated environment to create a secure and enjoyable public area was one of the most significant tasks. The brownfield property had previously been utilized as a dump and storage yard. The Huangpu River's water was excessively filthy, unfit for swimming or pleasure, and lacking aquatic life. Flood control was also a problem and an alternate flood control design was required since the current 22-foot-high concrete floodwall, along with daily tide changes, created an inaccessible, muddy, and littered beach. The linear waterfront site's design posed a third problem. It would be difficult to create a full wetland to encourage water cleansing because it is quite narrow at several locations. Access and pedestrian movement were particularly difficult due to the tight points. The park design would have to handle vast numbers of expected visitors for the 6-month Expo while also establishing an accessible and attractive human-scale public park in the long run. (LPS-CSB- 424, 2011)</p> |
| Project's Concept | <ul style="list-style-type: none"> Houtan Park was designed to highlight sustainable technology for the 2010 Shanghai World Expo, entitled "Better City, Better Life," a part of Expo Site's main green space and later become a permanent waterfront park. Display the subject of the Expo, which is Humanism, in terms of nature, science, and technology. Adhere to the Expo concept of "Better City, Better Life." Meet the strategic goal of "Green EXPO and Ecological EXPO" <p>(LPS-CSB- 424, 2011; Yang, Y., et al., 2016)</p> |
| Introduction | <p>Houtan Park was built on a former industrial site for the 2010 Shanghai World Expo to show off green technology to a surge of visitors and is now a permanent public waterfront park. While promoting regional culture and enhancing the riverside for public use, the Park was built as a regenerative living organism that purifies dirty river water, mitigates urban floods, and promotes habitat and biodiversity. The Park extends along the Huangpu River for many kilometers, including natural and man-made wetlands that filter dirty river water and encourage native animals to return. Several reclaimed structures can be seen throughout the park, revealing the site's industrial background, while terraces planted with a range of traditional crops refer to the country's agricultural legacy. (LPS-CSB- 424, 2011)</p> |



Fig. (97) Site before and after, Source: Turenscape, 2017; World-Architects, 2017



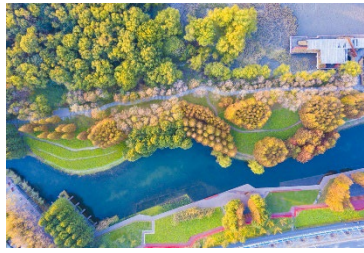
Fig. (98) Waterfront Park, Source: Turenscape, 2017



Fig. (99) Hanging garden's reclaimed structure, Source: Turenscape, 2017

Design Zones

- The park's heart is a linear constructed wetland, which is 1.7 kilometers (one mile) long and 5- 30 meters wide (16.5-100 ft). It acts as a living machine, filtering dirty water from the Huangpu River. The various stages of the purification system comprise: a 200-meter stone wall cascade, stepped fields and a U-pipe connection that capture contaminants, a 260-meter area with chosen plants for heavy metal absorption, a 250-meter area with selected plants for removal of nutrient, a cascading balcony area of 250 meter long for aeration, a water stability and a sand filtration area of 300 meters.



(LPS-CSB- 424, 2011; World-Architects, 2017)

Fig. (100) Park's heart, a constructed wetland, Source: Turenscape, 2017

- Using the idea of a living creature that can adapt, alter, and protect itself as a design concept. With a created wetland, cascades, and terraces that oxygenate the river water while removing pollutants, fertilizers, and sediment, Houtan Park was designed as a regenerative living system.
- Food production, flood control, water treatment, and habitat construction are among the regenerative design principles employed to turn the site into a living system that provides full ecological services in an educational and beautiful format. For the 2010 Expo, the site will serve as an innovative exhibition of ecological culture.
- The wetland also serves as a flood defense barrier between 20 - 1,000-year flood protection defenses.
- The former concrete floodwall was rebuilt with riprap, which protects the coastline from erosion while enabling habitat development along the water's edge.
- Terrace design eliminates the 18- foot elevation drop from road to the seashore, providing a tranquil valley where visitors can approach water and enjoy views from a range of platforms and thresholds.
- Resembling China's farmlands, terraces include an abundance of crops and bright native perennials as rice, sunflowers, and clover, providing seasonal appeal and knowledge of Shanghai's farming legacy.
- Riprap replacing the original concrete floodwall, allowing natural species to flourish along the river's border while preventing erosion of the coastline. (LPS-CSB- 424, 2011; World-Architects, 2017)

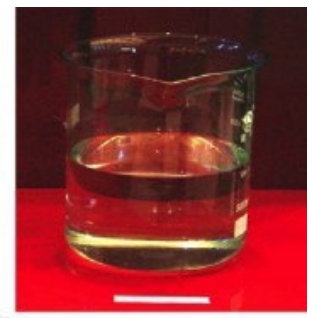
Design Development



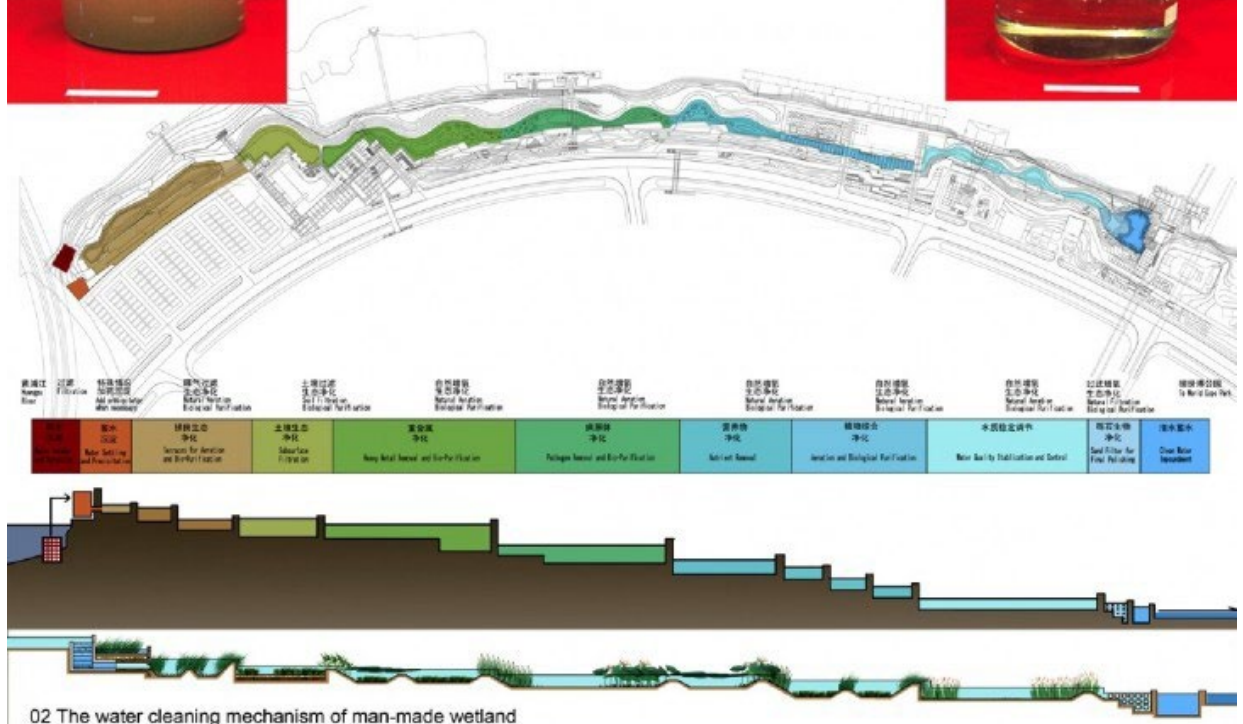
Fig. (101) Houtan Park's site plan (top) and Southwest aerial view (bottom), Source: LPS-CSB- 424, 2011; Turenscape, 2017



As water drops through the wetlands, the water filtration mechanism is revealed



Section



02 The water cleaning mechanism of man-made wetland

Fig. (102) The water quality, Source: Turenscape, 2017; LPS-CSB- 424, 2011

- Shanghai is the cradle of modern China, and the famous structures that have survived on the site have been turned into hanging gardens and observation platforms. The site's industrial character is highlighted via the reuse of industrial structures and resources; the site's steel was utilized to make the steel arbour and shade structure, the "Hanging garden" and architectural features, all of which make reference to the industrial past of the site.

Material

- The hanging gardens, steel arbours and shade structures, paved areas, and architectural features were created utilising 37 tonnes of steel and around 34,000 post-industrial bricks discovered on the site, saving an estimated \$17,300 in material costs. (LPS-CSB- 424, 2011; Rottle, N., et al., 2011)



Fig. (103) Park's Industrial Spirit,

Sources: World-Architects, 2017; Turenscape, 2017

- The 'hanging garden,' which was turned from structure of a factory, and the landscaped port, are among the several platforms and enclosed 'containers' that serve as nodes on the pedestrian network, creating bigger vistas for small groups to meet.
- To manage the area, a tiered approach was adopted, with walkways that cycle walkers through the site, through the wetlands, and out to the river, where a sequence of piers gives ferry water approaches to the park.

Public Open Space

- Park's aesthetic traits and ecological roles assure its long-term success beyond the Expo. (LPS-CSB- 424, 2011; World-Architects, 2017)



Fig. (104) Pedestrian pathways through site, wetlands and river, Sources: World-Architects, 2017; Turenscape, 2017

Public Recreational areas

- The park's three principal elements are an environmentally recovered landscape, urban agriculture, and industrial spirit, which are knitted together by a network of trails that educate visitors about green infrastructure inside a vibrantly recovered recreational space.
- A series of thresholds throughout the wetland's winding valley offer visual appeal and a retreat inside the busy global exhibition, with possibilities for enjoyment, learning, and research.
- A primary loop of 5.25 kilometres of pedestrian walking routes with perpendicular promenades crossing the wetland. Visitors can reach the interior regions of the living environment through many walkways that go through the terraces. Decomposable bamboo is used to construct the environmentally friendly boardwalks.
- Nodes in the pedestrian network, such as the 'hanging garden' and a floating landscaped dock, were built as platforms and designated spaces where small groups might gather.

(LPS-CSB- 424, 2011; World-Architects, 2017)

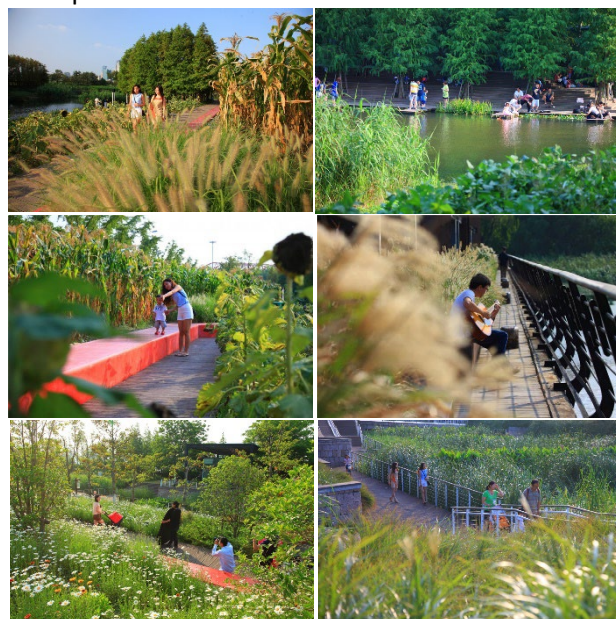


Fig. (105) Recreational areas and boardwalks around the site, Source: World-Architects, 2017

Impressive Features

- Hanging gardens were created above the teahouses in the park using recycled industrial buildings.
- Sunflowers and rice, among other crops, show tribute to China's agricultural legacy.
- The previous concrete levee was rebuilt with riprap, that preserves the coastline from erosion while also allowing for habitat development at the riverbank.

(LPS-CSB- 424, 2011; World-Architects, 2017)

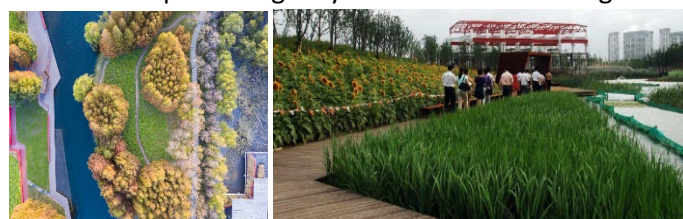


Fig. (106) Variety of crops and industrial structures, Source: Turenscape, 2017

Landscaping Important features

- The terraced wetland is linked with boardwalks for pedestrian circulation and viewing platforms overlooking the water. The terraces enhance the environment along the wetland by providing areas that invite visitors to engage the living system, with walkways that absorb and attract people to circulate around the park, much like sponge's capillaries.
- Rip-rap helps to preserve the shoreline from erosion while also providing habitat along the water's edge.

(LPS-CSB- 424, 2011)

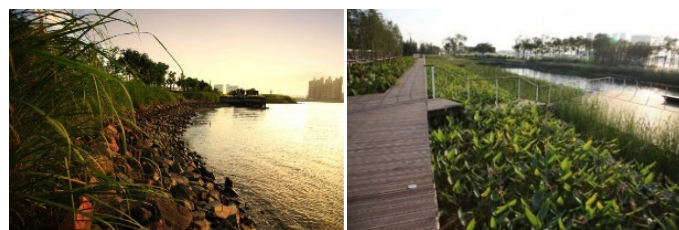


Fig. (107) Riprap and terraced wetland, Source: LPS-CSB- 424, 2011

Quality achieved:

- Turenscape's initial project, Houtan Park, utilized just biological processes for water purification.
- Showed state-of-the-art design and construction processes effectively.
- The park's effectiveness has resulted in eight national design patents and 20 to 30 additional ecological water purification projects using procedures developed for Houtan Park, where the firm is using comparable approaches.

(LPS-CSB- 424, 2011)

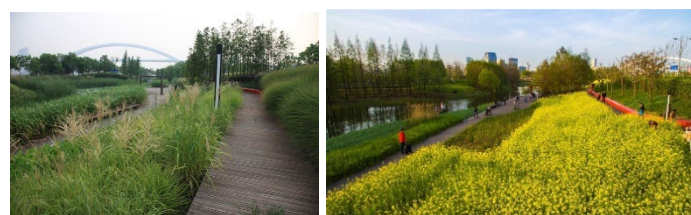


Fig. (108) State-of-the-art design, Source: LPS-CSB- 424, 2011; Turenscape, 2017

- Carbon sink • Sewage disposal • Providing animal habitat • Native biodiversity protection
- Water and soil conservation • Water saving • Waste recycling • Providing recreation
- Scientific education • History and cultural memory • Low maintenance cost (Yang, Y., et al., 2016)

BEFORE

AFTER

Achievement



Fig. (109) A view from a comparable point prior to the park's creation



Fig. (110) A view from a similar point after the park was built

Source: LPS-CSB- 424, 2011

Water

- Daily treat of up to 634,000 gallons of contaminated river water.
 - Using purely biological processes in upgrading the water's quality from Grade V (inappropriate for human contact) to Grade II (fit for landscape irrigation).
 - Between 20-year and 1,000-year flood mitigation floodwalls, the wetland serves as a flood prevention buffer.
- (LPS-CSB- 424, 2011)

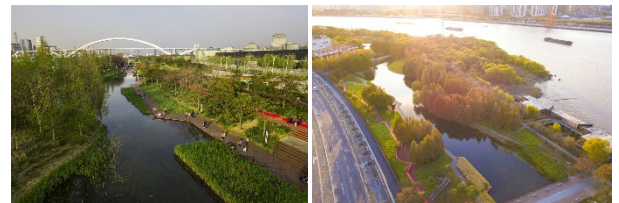


Fig. (111) Ecological process for water treatment, Source: Turenscape, 2017

Flora

- Significantly improved the site's biodiversity, with 93 plant species.
- Site has reintroduced a wide range of native species.
- Metasequoia, willow, privet, and camphor trees were among the 585 trees planted across the park.
- More than 70 aquatic invertebrates, 36 woody vegetation species, 50 herb vegetation species, and roughly 7 crop species.
- Bamboo and Chinese Redwood groves operate as barriers along the pedestrian routes, creating 'rooms' where modern art and industrial artefacts are displayed.

(LPS-CSB- 424, 2011; Rottle, N., et al., 2011)

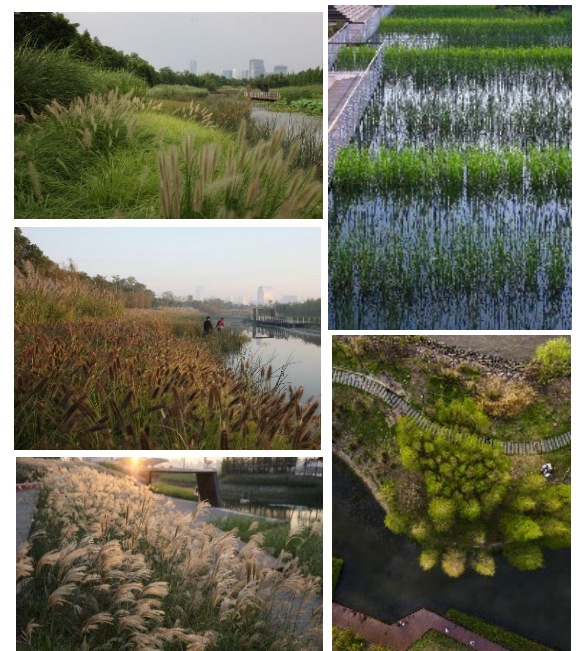


Fig. (112) Biodiversity Enhancement, Source: Turenscape, 2017

Fauna inventory

- Massively increased the site's biodiversity, with over 200 kinds of animals recorded.
 - Observe of 73 aquatic animal species, 20 bird species, 29 insect species, 2 amphibian species, 8 reptile species, 2 mammalian species, and 2 arthropod species..
- (LPS-CSB- 424, 2011; Rottle, N., et al., 2011)

Area Re-naturalized

- Houtan Park was designed as a regenerative living system with a manmade wetland, cascades, and terraces that oxygenate the river water and remove pollutants, nutrients, and sediment, based on the design idea of a living creature that can adapt, evolve, and defend itself.
- Riprap replaced the original concrete floodwall, allowing native species to flourish along the river's bank while also preventing erosion along the shoreline.

(LPS-CSB- 424, 2011; World-Architects, 2017)



Fig. (113) Design concept of a living organism, Source: Turenscape, 2017

Environmental Strategies:

- Carbon Dioxide Absorption
- Contaminated Land and Water Purification
- Sustainable Flood Mitigation Approach
- Offer a natural habitat for native flora and fauna

Environmental & Economic Strategies

- Waste Recyclability

Strategies

Social Strategies

- Design Path System based on Landscape Practice
- Establish Historical and Ecological Site

Economic Strategies

- Low-Cost Maintenance

(Yang, Y., et al., 2016)

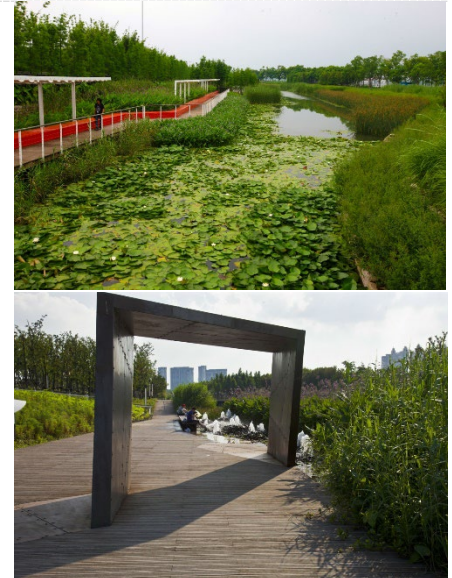


Fig. (114) Better City, Better Life, Source: Turenscape, 2017

SOCIAL

During the 2010 Shanghai World Expo, about 590,500 visitors were provided with recreational and educational options. Residents of the city and visitors from all around China and the world continue to benefit from the park.

ECONOMIC

Socio/Economic Benefits

- When compared to the normal cost of treating water in a water treatment facility in China, using natural processes to remove polluted river water has a value of around \$131-145,000 per year.
- The nearby Expo Park uses 264,000 gallons of water cleaned by Houtan Park's wetland purification system in the water features, saving \$116,800 per year in water expenses.
- Reusing 37 tons of steel and nearly 34,000 post-industrial bricks discovered on the site reduced trash and saved an estimated \$17,300.

(LPS-CSB- 424, 2011; Rottle, N., et al., 2011)

4.4.3 Case study's Environmental Analysis Summary according to proposed indicators

Table (9) Shanghai Houtan Park's Environmental Analysis Summary, Source: Author, from Rottle, N., et al., 2011

| Category | Indicator | Sub-Indicators /Description | Type | Output |
|-----------------------|---------------------------------|-----------------------------|--------------|--|
| Environmental Aspects | Climatic Aspects | Air Quality | Quantitative | • Sequesters an estimated 242 tons of carbon annually in park's extensive wetlands, perennial plantings, and trees. |
| | | Urban Micro-Climate | Quantitative | |
| | | Carbon Footprint | Quantitative | |
| | Sustainability | Energy | Quantitative | No Data Available |
| | | Materials | Quantitative | <ul style="list-style-type: none"> • Reclaimed steel from the site was used to create the steel arbor and shade structure, the 'hanging garden', and architectural details, invoking the site's industrial past. • Reused 37 tons of steel and roughly 34,000 post-industrial bricks found on the site |
| | | Solid/ Liquid Wastes | Quantitative | Reusing steel and bricks found on the site to create the hanging gardens, steel arbors and shade structures, paved areas, and architectural details, saved an estimated \$17,300 in material costs. |
| | | Soil | Quantitative | No Data Available |
| | Biodiversity; Habitat Diversity | Flora (Vegetation) | Quantitative | Increased the biodiversity of the site dramatically, with 93 species of plants |
| | | Fauna | Quantitative | over 200 species of animals observed. |
| | Water | Water Reused | Quantitative | Cleans up to 634,000 gallons of polluted river water daily, improving the water's quality from Grade V (unsuitable for human contact) to Grade II (suitable for landscape irrigation) using only biological processes. |
| | | Water Quality | Quantitative | |

4.4.4 Relevance to Case study, 10th of Ramadan Park

1- Design Zones

- A linear constructed wetland through the center of the park, with a long path and narrow width
- Living machine wetland, treating contaminated water, with different cleaning system stages
- Selected plants to adsorb heavy metals, nutrient removal, cascading terraces for aeration, water stability and sand filtration area.

2- Material

- Reuse of available materials from the site

3- Public Open Space

- A layered approach with circulating pedestrian paths around the site and through the wetland
- Terrace design allow access to water and aesthetic views from numerous platforms and thresholds
- Abundant mix of vegetation and colorful native perennials provide seasonal interest
- Aesthetic qualities and ecological functions ensure continuous success

4- Public Recreational areas

- Twisting valley along the wetland creates a series of thresholds creating visual aesthetic interest
- Opportunities for recreation, education, and research.
- Pedestrian walking paths intersect the wetland and allow access to inner spaces of living landscape
- The ecofriendly boardwalks are made of decomposable bamboo.
- Platforms and nodes on the pedestrian network create areas for gathering

5- Impressive Features

- Structures for hanging gardens above the center of the park.
- Concept of a living organism with the ability to adapt, change, and protect itself

6- Landscaping Important features

- Terraced wetland interconnected with pedestrian circulation and platforms provide water views
- Riprap protects the waterside from erosion and creates habitat along the water's edge.

7- Water

- Improving the water's quality to be suitable for landscape irrigation using only biological processes

8- Flora

- Reintroducing large variety of native plants
- Use of native bamboo and other species as screens along the pedestrian paths and to create 'rooms'

9- Fauna inventory

- Over 200 species of animals observed as a result of introducing various habitats.

10- Area Re-naturalized

Design concept of a living organism, built as a regenerative living system with a constructed wetland, cascades, and terraces that oxygenate the water and remove pollutants, nutrients, and sediment.

11- Strategies

- **Environmental Strategies:** Absorb Carbon Dioxide, Purify Contaminated Land and Water, Sustainable Flood Control System, Provide Habitat for Native Plant and Animal
- **Environmental & Economic Strategies:** Waste Recycling
- **Social Strategies:** Create Path System with Landscape Experience, Create Historical & Ecological Site
- **Economic Strategies:** Low Maintenance

12- Socio/Economic Benefits

SOCIAL: Provide recreation and educational opportunities to residents and visitors

ECONOMIC: Saving of water cost through water treatment and reuse in the water features.

4.5 South Los Angeles Wetland Park

4.5.1 Introduction:

Location: Los Angeles, USA, 2011

Climate Zone: Hot-summer Mediterranean

Scale: Small-scale Park; 0.036 km²

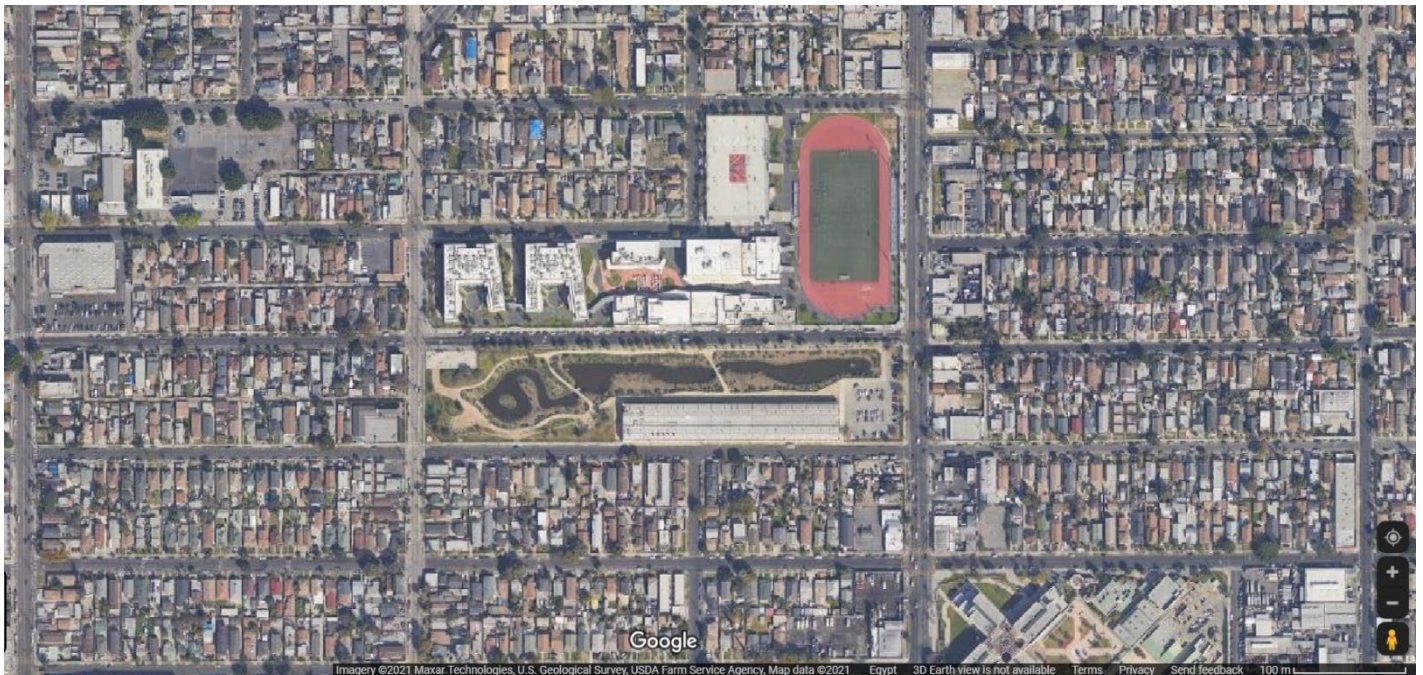


Fig. (115) South Los Angeles Site Location, Source: Google Map, Date accessed: Sep. 1, 2021



Fig. (116) South Los Angeles Wetland Park's Location, Source: Google Map, edited by Author, Date accessed: Sep. 1, 2021

4.5.2 Analysis:

Case Study 5 South Los Angeles Wetland Park

| | |
|----------------------------|---|
| Location | Los Angeles, USA |
| Area | 36,421.7 m ² , 0.036 km ² , 9 acres (Small-scale Parks) |
| Designer | Psomas, Mia Lehrer + Associates |
| Project Type | Park/Open space Wetland creation/restoration |
| Climate Zone | Hot-summer Mediterranean |
| Former Land Use | Brownfield The area was a lead-contaminated bus station run by Los Angeles Metro Transportation Authority. |
| Cost US\$ Completed | \$12.4 million 2011 |

Challenges & Climate Condition

As part of the California Environmental Quality Act (CEQA), a stormwater quality enhancement project with at least 4-acre water body was needed, which also serve as a park in a flat, local site with no natural water supply. A constructed wetland with a park was the design key. The concept provided a visual facility while cleansing water from a 525-acre sewage shed in South LA by channeling runoff from grey infrastructure below to the surface. As the marsh would dry up during summertime, extreme weather and climate change implications were addressed, and the park was planned such that drinkable water could be piped in and cycled around the site. (LPS-CSB- 1041, 2016)



Fig. (117) LA Park wetland, Source: LAParks, 2022

Project's Concept

Proposition O funds was used to build the park, which promotes public health and complies with federal Clean Water Act criteria. The park was built with the primary objective of water treatment; hence the wetland system takes up a large portion of the land. (LPS-CSB- 1041, 2016)



Fig. (118) Former Transit Maintenance facility, Source: Psomas, 2014

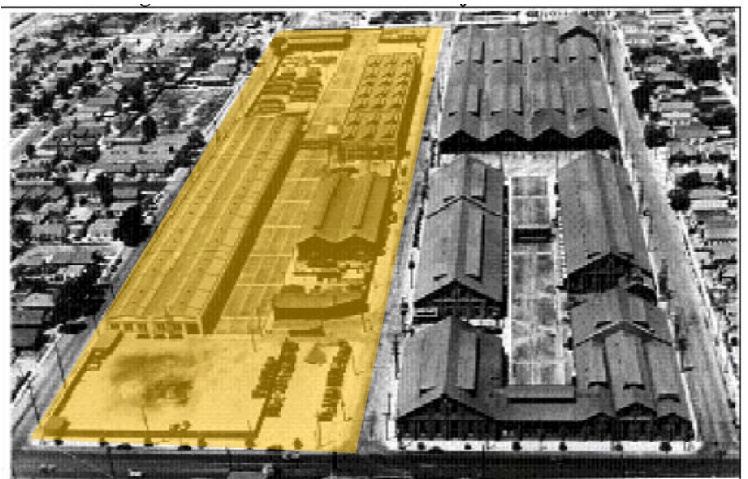
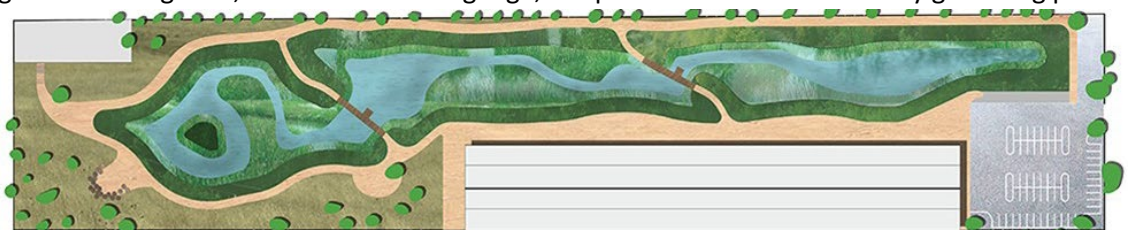


Fig.(119) Aerial view of intended Wetlands Park's site circa 1930s., Source: Preliminary Design Report, 2008, edited by Author

Introduction

South LA Wetland Park is a useful and appealing California environment that was transformed from an old bus yard and brownfield in the heart of a highly populated town. Located in the Los Angeles River watershed, the park catches and filters urban stormwater runoffs through wetlands with the emerging riverside swamp habitat at the center, while tackling environmental and social fairness by providing a neighborhood-revitalizing facility in a historically neglected district. The park manages urban runoff from a 525-acre watershed by diverting water from the existing piped flood control system through an 81,760-sf built wetland system. With several pathways, boardwalks, viewing platforms, picnic spaces, a natural rock-garden seating area, and informative signage, the park serves as a community gathering place.



(LPS-CSB- 1041, 2016)

Fig. (120) Park's series of wetlands, Source: LPS-CSB- 1041, 2016

The park's development resulted in the creation of a series of wetlands that filter urban stormwater runoff before reintroducing it to the region's water supply. (LPS-CSB- 1041, 2016)

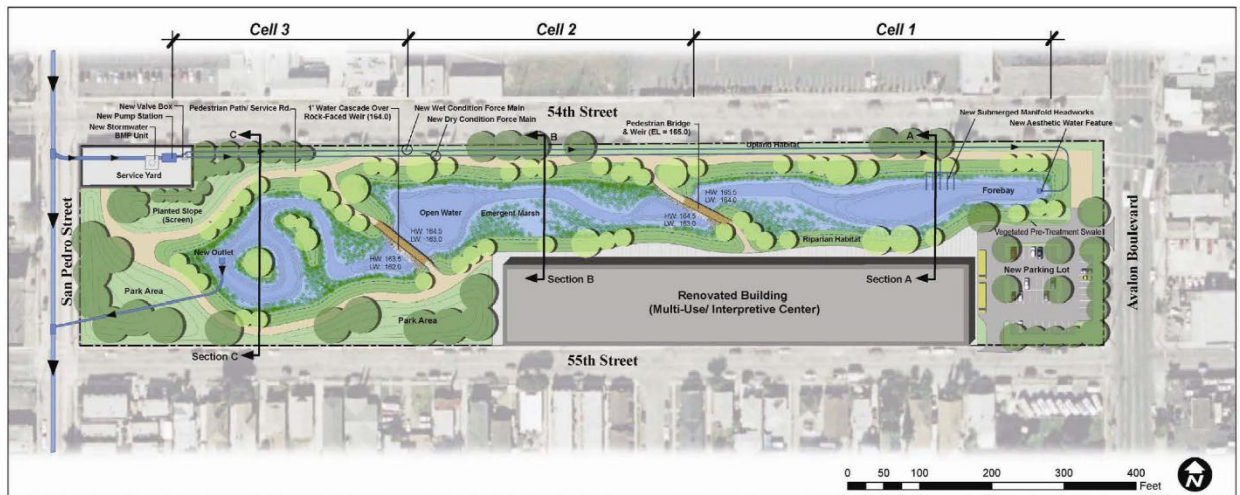


Fig. (121) Wetlands Park Site Layout proposal, Source: Draft EIA report, 2007 edited by Author

Design Zones

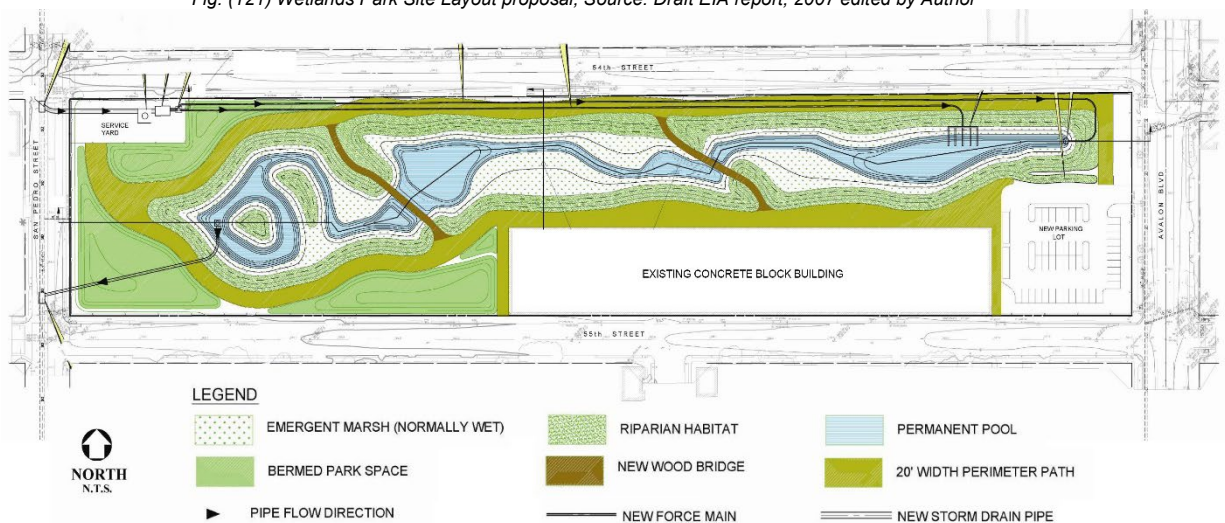


Fig. (122) Wetlands Park preliminary Site Plan proposal, Source: Draft EIA report, 2007

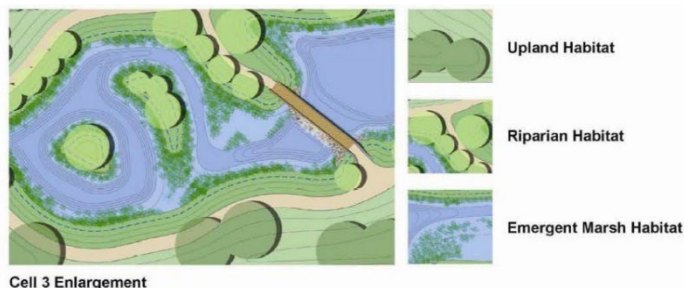


Fig. (123) Wetlands Park preliminary Site Plan proposal for Cell 3, Source: Draft EIA report, 2007

Design Development



Fig. (124) Wetlands Park design development, Source: LPS-CSB- 1041, 2016

The region has a mix of residential sections, nice old mansions, and a few areas of factories and warehouses.

- 1- The initial promontory purifies water by trapping sediments and utilizing phytoremediation.
- 2- The cleansed water re-enters the Los Angeles stormwater system through the western outflow.
- 3- Low-maintenance native grasses bordering the constructed wetland.
- 4- The park's northern border is shared with the school. The further edges bordered by 1-2-story residences.

(Bonin, M., 2021; LPS-CSB- 1041, 2016)

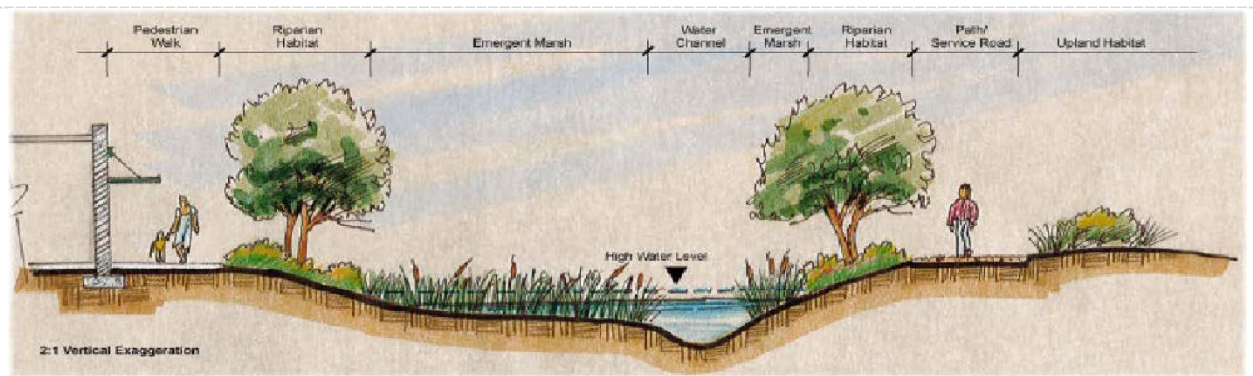
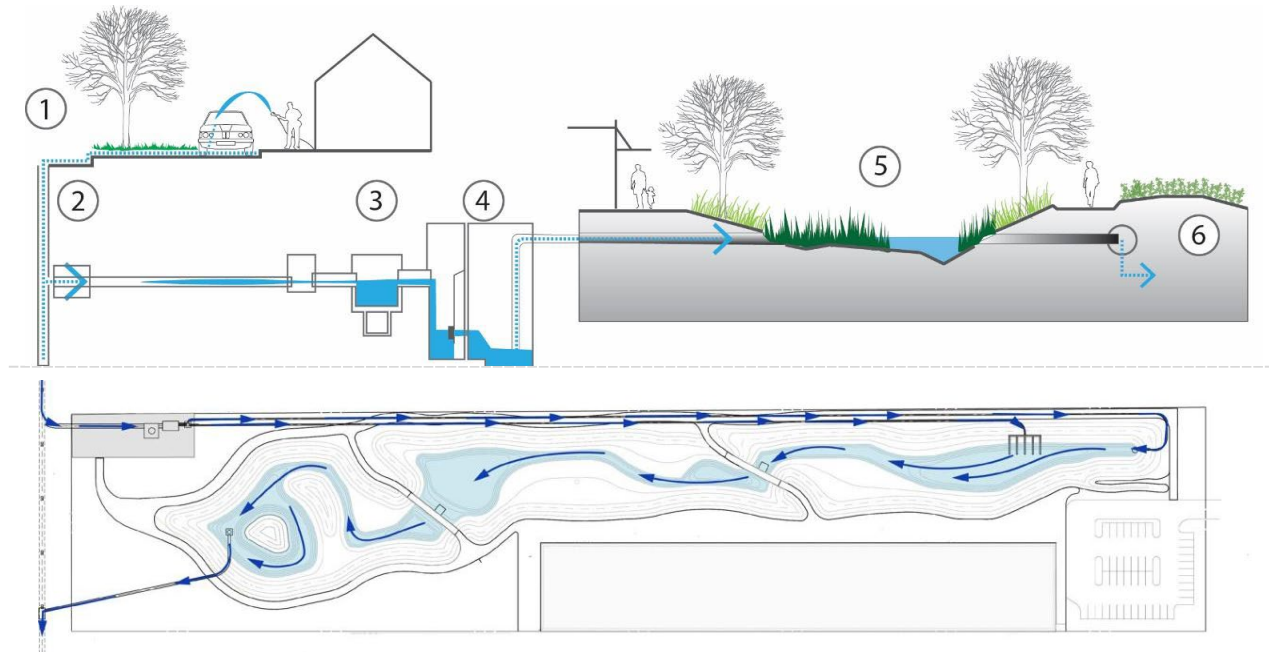


Fig. (125) Wetlands Park conceptual Section rendering, Source: Draft EIA report, 2007



Sections

Fig. (126) Wetlands Park stormwater runoff treatment design, Source: Shannon, K., et al., 2016



Fig. (127) Site Signage Diagram explanation of the storm water runoff, Source: Zofnass, 2016

- (1) **STORM DRAINAGE:** The subsurface storm drainage system collects urban storm water runoff.
- (2) **DIVERTER:** The stormwater is rerouted to pre-treatment system that filters oil, trash and other materials from storm water before it is treated.
- (3) **SEPARATOR:** A hydrodynamic separator is used to separate oil, grease, and garbage.
- (4) **TRASH SCREEN:** Then as storm water runs through a trash screen, any leftover debris is eliminated.
- (5) **CONSTRUCTED WETLAND:** Storm water is currently "pre-treated" before being sent to the wetland. Pollutants such as nitrates, phosphates, and bacteria are eliminated by wetland plants in the constructed wetland. Pollutants are absorbed by the plants and removed from the water.
- (6) **STORM DRAIN:** Any surplus water is now cleansed and returned to the storm drain system.

The process begins when water from the 525-acre watershed enters the underground stormwater system. The second step include a diverter intercepts stormwater. Then the water goes through a separator, which removes oil, grease, and trash. Next a trash screen removes any remaining litter from the water. Finally, the excess water is released back into the stormwater system after cleaning.

(Shannon, K., et al., 2016, Zofnass, 2016)

Material

- Before urban runoff reaches the natural system, a pretreatment hydrodynamic filter removes silt, garbage, oil, grease, fuel, and heavy metals. (Removes 100% oil and grease, 75% of bacteria, 96 % total suspended solids, 41% nitrate, and 34% phosphorus)
- Entire site was covered in impermeable material.
- A 0.5-mile leisure route built of 65,000 square feet of decomposed granite along the side of the filtration ponds.

(Shannon, K., et al., 2016; Zofnass, 2016)

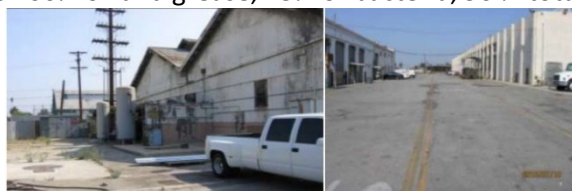


Fig. (128) Storage tanks and site's poor condition prior to Park's construction, Source: Zofnass, 2016

Public Open Space

- "Mast," a full-scale, sculptural copy of the great mast of the San Salvador, one of the ships that guided the discovery of California's coast in 1542, was exhibited as part of LA's Public Art Biennial in the summer of 2016. "Mast" served as a reminder of colonialism's intricacies and varied legacy while also offering shade for tourists.
- Visitors are educated about wetland ecosystems, native habitat and species of California, and physical and biological phenomena specific to wetlands.
- In the north-south direction, wooden bridges traverse the constructed wetlands and provide gathering places for diverse groups of residents and youngsters.
- Riparian habitat, pathways, trails, viewing decks, outdoor classroom, instructional signs, passive recreational area, and picnic seats are all part of the multi-benefit project.

(LPS-CSB- 1041, 2016; Zofnass, 2016; Psomas, 2014)



Fig. (129) Park's Open spaces, Source: LPS-CSB- 1041, 2016; Bonin, M., 2021

Public Recreational areas

- Among the park's community-friendly features are:
 - An amphitheater for outdoor classrooms
 - An informative booth with information on the park's function, flora, and Fauna
 - Walking path around the treatment wetlands for enjoyment
 - Places for picnics with benches
 - Viewing bridges and platforms that provide a view of the marsh
- The park appeals and serves to people of all ages offering a range of activities such as running, fishing, birding, and dog walking.
- One of the project's objectives was for the park to serve as an educational resource for surrounding schools. Despite this, the park has never been used for formal educational purposes. This is a lost potential since the wetland offers a unique learning environment.
- The park has improved community residents' quality of life by allowing them to enjoy nature while strolling, running, and walking their pets in a nearby nature park.
- At the park's entrance, informative navigation and a distinctive educational signage informs visitors about Prop O and the park's commitment to storm water treatment.

(LPS-CSB- 1041, 2016; Zofnass, 2016)

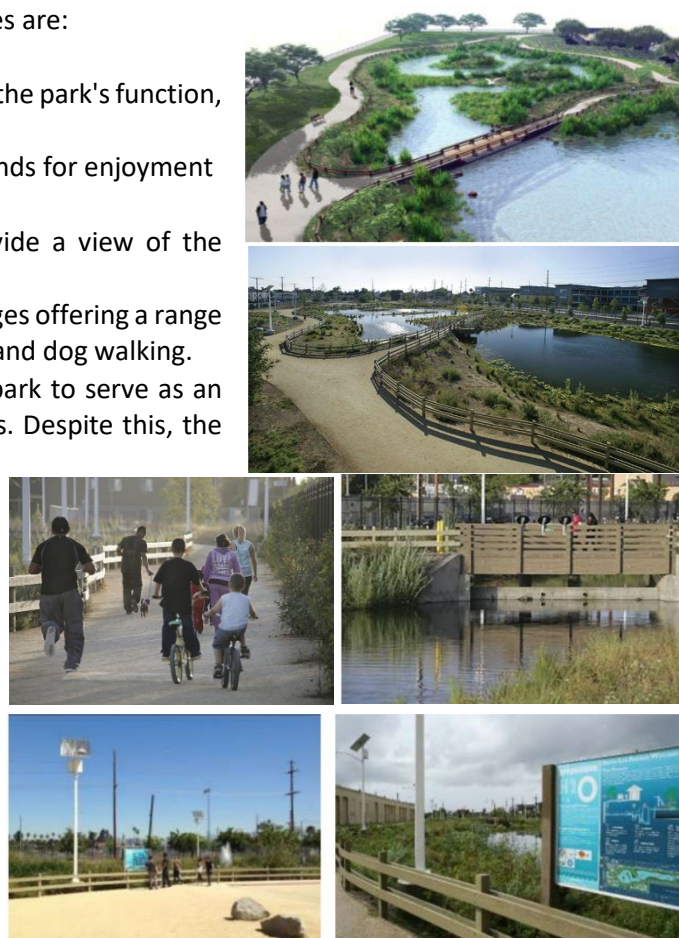


Fig. (130) Recreational areas and educational signage at Park's entrance, Source: Zofnass, 2016

Impressive Features

- Bioretention facility, biowaste, and permeable pavers are among the proposed design features. Before being released back into the stormwater conveyance system, the diverted runoff will be treated in series by a hydrodynamic separator unit and a constructed treatment wetland.
- Park visitors may jog or stroll along a 0.5-mile leisure track built of 65,000 square feet of decomposed granite that runs beside the filtration ponds.
- Encouraging visitors to explore the park to get a feel of the dynamic community that exists. Visitors may enjoy a stroll through the ancient warehouse building or through the pools, observing birds, turtles, and people jogging, or simply spending quality time with their families.
- Park is an environmental protection asset that is utilized to clean up cities' pollutants. A paradigm shift from purely aesthetic or recreational considerations to efficient ecological design. The impact is transcendent, with a significant number of residents enjoying the park and in turn elevating their community. (ASLA, Case-236, 2011; LPS-CSB- 1041, 2016; Bonin, M., 2021; Psomas, 2014)



Fig. (131) Wetlands Park proposed renderings, Source: ASLA, Case-236, 2011

Landscaping Important features

- Total of 41 LED lights with solar panels were installed along the pedestrian pathways and in the parking lots, to offer security overhead illumination reducing the site's energy consumption. Solar panels are mounted on the light pole's top and stored electricity in gel cell batteries.
- Solar illumination was installed as part of the project to encourage alternative energy sources. Solar energy is expected to contribute 66 % of park's yearly operational energy consumption, saving 77% of energy use by completely separating it from the electrical grid.
- Surrounding leisure trail is now a favorite hangout spot
- Signage instructs park visitors on the various sorts of planting areas and how water passes and cleansed through the site, creating a learning opportunity for the nearby elementary and high schools. (LPS-CSB- 1041, 2016; Zofnass, 2016)



Fig. (132) Park's Impressive features, Source: LPS-CSB- 1041, 2016

Quality achieved:

- The project aids in community transformation by changing a brownfield site into a unique public park space in a densely populated area. The park achieved the Envision Platinum award, the highest level in (ISI) assessment system for reviving community while treating urban runoff.
- The project received the highest score, 93 %, (156 out of 168), from the restoration of damaged soils to its role as an ecological catalyst that enhance species diversification and stormwater management, the qualities of the South LA Wetland Park reflect great sustainable options for the challenges presented in Natural World category.
- Catalytic in the local community transformation
- A novel paradigm in the projects aiming to solve the lack of urban green space, a public park has been built on the same site as a storm water management facility.
- During rainy season, rainwater from the typical storm sewer system reaches the forebay, reducing scour, helping to suspend sediments, and allowing water to enter the wetland system more easily.
- Lowers the localized heat island impact by 8.5 degrees Fahrenheit. The park's construction also resulted in the elimination of 87.5 % of the heat-producing surfaces that were previously there. (Psomas, 2014; Shannon, K., et al., 2016; LPS-CSB- 1041, 2016; Zofnass, 2016)

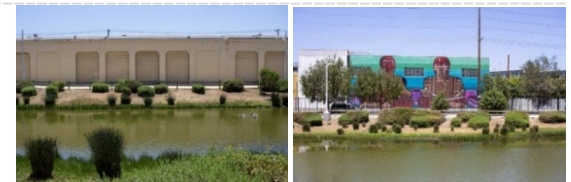


Fig. (133) Park's Open spaces, Source: Bonin, M., 2021

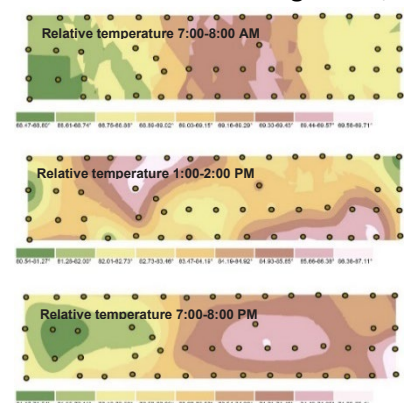


Fig. (134) Relative Temperature study, Source: Shannon, K., et al., 2016

BEFORE

AFTER

Achievement



Fig. (135) Previously a lead-polluted bus depot site managed by the Los Angeles Metro Transportation Authority



Fig. (136) Currently fully operational park, purifying urban stormwater runoff while providing community recreational possibilities

Source: LPS-CSB- 1041, 2016

The South Los Angeles Wetland Park is a daring, integrated, and sustainably constructed project that catches and treats urban runoff while also providing a revitalizing park for the community.

(Psomas, 2014)

Water

- The site's stormwater runoff is gathered in the northwest corner, directed through an underground pretreatment system, and then cycled over the constructed wetland. Surplus water that has been cleaned is returned to the regular stormwater system on the site's western side.
- When the forebay fills up, water from the storm sewer is no longer pushed into the system, and the water is progressively released into the marsh. Psomas built treatment facilities that comprise a 3-cell, 4.5-acre treatment wetland, structural pretreatment, high and low flow pump station, and diversion from a large existing subterranean storm drain. The wetland treats some of the runoff from the surrounding 525-acre catchment and utilizes it to keep the wetland sustained.
- Treats up to 14,000 gallons of stormwater runoff daily from the 525-acre watershed, enough to treat all runoff in dry season.
- During months of low water flow, marsh plants require less than 35% of the irrigation that a standard grass area would require, which amounts to between 0.4 and 0.5 inches per week, as opposed to 1.5 inches per week

(LPS-CSB- 1041, 2016; Shannon, K., et al., 2016; Psomas, 2014)



Fig. (137) Park's wetland & stormwater runoff, Source: KCET, 2012

Flora

- wetland plant species included Sandbar willows (*Salix exigua*), California bulrush (*Schoenoplectus californicus*), tall flatsedge (*Cyperus eragrostis*), and yerba mansa (*Anemopsis californica*). California rose (*Rosa californica*), hummingbird sage (*Salvia spathacea*), mulefat (*Baccharis salicifolia*), and coast live oak (*Quercus agrifolia*) are upland species.
- A total of 88 trees were planted around the perimeter of the wetland.
- Trees sequester average 1.82 tons of carbon from atmosphere annually, equivalent of driving a single passenger vehicle about 4,000 kilometres.
- Runoff from the parking lot is directed into the wetland by a vegetated swale comprising Western sycamores (*Platanus racemosa*), holly-leaved cherry (*Prunus ilicifolia*), and deer grass (*Muhlenbergia rigens*).
- On-site, 4.5-acres wetlands and 4.5-acres upland habitat were designed.
- To endure flooding and drought, 40 species of open-water, emergent marsh, riparian, and upland plants were chosen.

(LPS-CSB- 1041, 2016; Shannon, K., et al., 2016)



Fig. (138) Park's Flora Enhancement, Source: Zofnass, 2016; KCET, 2012



Fig. (139) Park's various vegetation species, Source: Shannon, K., et al., 2016

Fauna inventory

- Provides habitat for range of wildlife species, mainly birds, like black-crowned night heron (*Nycticorax nycticorax*), Anna's hummingbird (*Calypte anna*) and mourning dove (*Zenaida macroura*)
- Nine distinct species have been reported on iNaturalist.org, and 35 distinct species have been documented on eBird, making it an urban birding hotspot in the Los Angeles area.
- As a result, it has become a popular urban birdwatching destination in the Los Angeles region.
- The wetland pools are planned to have a depth of at least 5 feet, which encourages water movement, improves wind-driven oxygenation, restricts emergent plant colonization, enables particulate matter disposition, and discourages mosquito breeding. The sun's UV rays aid in the reduction of germs and bacteria in stormwater as it flows through the wetland system.

(LPS-CSB- 1041, 2016; Shannon, K., et al., 2016)



Fig. (140) Park's Fauna Enhancement, on a former brownfield, increasing biodiversity and creating new habitats, Source: Zofnass, 2016

Area Re-naturalized

- The wetland pools are planned to have a depth of at least 5 feet, which encourages water movement, improves wind-driven oxygenation, restricts emergent plant colonization, enables particulate matter disposition, and discourages mosquito breeding. The sun's UV rays aid in the reduction of germs and bacteria in stormwater as it flows through the wetland system.
- Despite the planting of 88 trees along the wetland's perimeter, park visitors have complained about the lack of shade, which has a detrimental impact on park utilization during Southern California's scorching summers. More shade, whether through new trees or a building, would certainly boost park utilization by the community.
- The project included two parts, Phase I involving the development of the marsh, natural, and park areas and Phase II involving the adaptive reuse of existing structure on site. The building was built to hold an explanatory museum, communal area, and restrooms. Phase II, however, has not been finished owing to financing concerns. As a result, park visitors are unable to use the restrooms. This might have been avoided by including restrooms into Phase I or ensuring Phase II funds.

(LPS-CSB- 1041, 2016)



Fig. (141) Park's Flora Enhancement, Source: KCET, 2012; Bonin, M., 2021

Strategies

Reclaim, Maintain, Sustain

Psomas pursues alternative strategies, such as Reclaimed and Recycled water and the capture of stormwater for using in Park's irrigations. (Psomas, 2014)

SOCIAL

- In the Southeast Los Angeles – North district, which had the city's second lowest park acreage per capita, the per capita park acreage was increased by 11%, from 0.54 acres to 0.6 acres per 1,000 persons. The nearby communities' median household income is \$29,074, only 58% of city's median.
- Encourages people to participate in recreational and social activities, as reported on social media platforms: 33% fitness, 15% nature, and 6% cultural or social events.
- As part of this renovation, the Paint Shop Building, a significant historical structure, was saved, with plans to utilize it in Phase II. The structure was the first of its kind in the western United States, constructed with concrete tilt-up walls. Robert H. Aiken, a prominent and vital inventor in concrete construction, is only known to have built this one structure in California.

Socio/Economic Benefits

ECONOMY

- Contributes to a \$243.43 per square foot gain in house value for properties inside a three-block by three-block square centered on the park, compared to \$217.14 for homes beyond this area and within a five-block by five-block square centered on the park. The cost per square foot of the closer home residences has increased by 12%.
- Produces 8,081 kWh of energy each year, accounting for 66% of the site's total energy use. This saves \$1,700 in energy bills annually. (LPS-CSB- 1041, 2016; Shannon, K., et al., 2016)

4.5.3 Case study's Environmental Analysis Summary according to proposed indicators

Table (10) South Los Angeles Wetland Park's Environmental Analysis Summary, Source: Author, from Shannon, K., et al., 2016

| Category | Indicator | Sub-Indicators /Description | Type | Output |
|-----------------------|---------------------------------|--|--------------|--|
| Environmental Aspects | Climatic Aspects | Air Quality - Air quality: Improvement in air quality due to increased vegetation cover | Quantitative | <ul style="list-style-type: none"> Sequesters an estimated 1.82 tons of atmospheric carbon annually in trees, the carbon equivalent of driving a single passenger vehicle almost 4,000 miles. Reduces localized heat island effect by 8.5°F. Construction of the park also resulted in the removal of 87.5% of the heat-producing surfaces which had previously been located onsite. |
| | | Urban Micro-Climate - Heat Island Effect: % of decrease in Heat Island Effect due to increased vegetation cover and water bodies | Quantitative | |
| | | Carbon Footprint - Carbon Footprint: amount of carbon dioxide and other GHG emissions associated with the wetland project compared to conventional treatment plant | Quantitative | |
| | Sustainability | Energy - Construction Energy Conservation: % of energy conserved during construction stage compared to conventional treatment plant - Operation Energy conservation: % of operational electrical energy conserved compared to conventional treatment operations measured over a specific temporal scale | Quantitative | Generates 8,081 kWh of energy annually, or 66% of the site's total energy use. This saves \$1,700 in energy costs each year. |
| | | Materials - Recycled Materials: % of materials that is recycled or acquired from onsite materials - Hazardous Materials: % of hazardous materials and chemicals employed in water treatment process compared to conventional treatment processes | Quantitative | <ul style="list-style-type: none"> Removes an estimated 100% of oil and grease, 75% of bacteria, 96% of total suspended solids, 41% of nitrate, and 34% of phosphorous from stormwater runoff. |
| | | Solid/Liquid Wastes - Quality/ Quantity of wastes: % of waste materials discharged during the treatment process | Quantitative | Removes an estimated 100% of oil and grease, 75% of bacteria, 96% of total suspended solids, 41% of nitrate, and 34% of phosphorous from stormwater runoff. |
| | | Soil - Quality/ Quantity of soil creation, preservation & restoration: % of fertile or restored soils | Quantitative | No Data Available |
| | Biodiversity; Habitat Diversity | Flora (Vegetation) - Number of Fauna and Flora species introduced into the habitat | Quantitative | 88 trees planted along the wetland's periphery |
| | | Fauna - Number of Fauna and Flora species introduced into the habitat | Quantitative | <ul style="list-style-type: none"> Serves as habitat for numerous species of wildlife, particularly birds Reported sightings of 9 different species, Recorded 35 different species, Making it an urban birding hotspot in LA area |
| | Water | Water Reused - Water Reused: % of water reused or reintroduced to the irrigation system. | Quantitative | Treats up to 14,000 gallons of stormwater runoff from the 525-acre watershed per day. This is sufficient capacity to treat all runoff during the dry season. |
| | | Water Quality - Water quality: % of pathogens removed through the constructed wetland | Quantitative | Irrigation Requires less than 35% of the irrigation for wetland plants than a traditional turf area would require during months of lowest water flow, which translates to between 0.4 - 0.5 inches/week, as compared to 1.5 inches per week. |

4.5.4 Relevance to Case study, 10th of Ramadan Park

1- Material

- During the wet season, precipitation runoff enters the forebay, which minimizes scour, helps suspend solids, and facilitates the water entering the wetland system.
- Reuse of decomposed granite in pedestrian trail along the pond

2- Public Open Space

- Adding of sculptural replica as cultural value for community while providing shade for visitors.
- Wooden bridges crossing the constructed wetland and serve as meeting spots for various groups of community members and youth

3- Public Recreational areas

- Providing an outlet for all age visitors and for a variety of different activities
- An educational asset for nearby schools.
- Informative wayfinding and educational signage at the entrance of the park.

4- Impressive Features

- Recreation trail made of decomposed granite along the filtration ponds provides a place for visitors
- Maintaining a depth greater than 5 ft in the wetland pools helps encourage water flow, enhances wind-driven water oxygenation, limits colonization of emerging plants, allows particulates to settle, and discourages mosquito breeding
- Exposure to UV rays from the sun helps reduce bacteria in stormwater as it moves through the wetland system

5- Landscaping Important features

- Solar powered lighting reduces the site's energy consumption.
- Impressive surrounding recreation trail
- Educational signage as an educational opportunity for visitors about vegetation species and zones and wetland treatment process

6- Water

- Stormwater runoff harvesting and treatment in the constructed wetland.
- Management of stormwater in case reaching capacity

7- Flora

- Introducing indigenous wetland plant species, planting of 88 trees along the wetland's periphery
- A vegetated swale with native species directs runoff from urban streets into the wetland
- Species of open-water, emergent marsh, riparian and upland plants of both flooding and drought tolerance

8- Fauna inventory

- Serves as habitat for numerous species of wildlife
- Creating an urban birding hotspot

9- Area Re-naturalized

- The wetland pools are designed to maintain a depth greater than 5 ft, which helps encourage water flow, enhances wind-driven oxygenation of the water, limits colonization of emergent vegetation, allows particulate matter to settle, and discourage mosquito reproduction. Exposure to UV light from the sun helps reduce the bacteria in the stormwater as it moves through the wetland system.

10- Socio/Economic Benefits

SOCIAL: Provide recreational and social activities opportunities to residents and visitors

ECONOMIC: Contributing to increase of home value within approximate blocks. The closer homes have an increased cost per square-foot higher than homes located outside of this area.

4.6 A comparative analysis of case study parks according to Indicators

Table (11) Comparative Analysis Summary of case study parks according to Indicators, Source: Author

| Case Study / Indicator | | Saudi Arabia | China | China | China | USA |
|------------------------|------------------|---|---|--|--|--|
| Background | Park | Wadi Hanifa | Tangshan Nanhu Eco-city Central Park | Tianjin Qiaoyuan Park: The Adaptation Palettes | Shanghai Houtan Park | South Los Angeles Wetland Park |
| | Location | Riyadh | Tangshan, Hebei, China | Tianjin, China | Shanghai, China | South Los Angeles |
| | Climate | Arid | Humid continental | Cold semi-arid | Humid subtropical | Hot-summer Mediterranean |
| | Type | Park/Open space Waterfront redevelopment Wetland creation/restoration | Park/Open space Wetland creation/restoration | Park/Open space Wetland creation/restoration | Park/Open space Waterfront redevelopment Wetland creation/restoration | Park/Open space Wetland creation/restoration |
| | Area | Large-scale Parks 15,009,790 m ² 15 million square meters, 3,709 acres, 15 km² | Large-scale Parks 6,300,955.4 m ² 6.3 million square meters, 1,557 acres, 0.63 km² | Medium-scale Parks 218,530 m ² , 54 acres, 0.22 km² | Medium-scale Parks 139,616.55 m ² 34.5 acres, 0.14 km² | Small-scale Parks 36,421.7 m ² 9 acres, 0.36 km² |
| | Former Land Use | Brownfield Parts were rubbish dump grounds; others were quarried for stone/sand. | Brownfield A coal mine reclamation project. A former 1,557-acre wasteland | Brownfield , A military shooting range, garbage dump, surrounded by slums and highways. | Brownfield A landfill and storage yard A former industrial site | Brownfield A lead-polluted bus depot owned by L.A. Metro Transportation Authority |
| | Importance | Previously Brownfield | Successfully demonstrated state-of-the-art design and construction techniques | The ecology-driven Adaptation Palettes has become a valuable and remarkable site of the community of Tianjin. | Achieve the strategic target of "Green EXPO and Ecological EXPO". then a permanent waterfront park | captures and treats urban stormwater runoff through a wetland with riparian and emergent marsh habitat at the center |
| | Cost | 160 million, Budget: \$1 billion | \$68,027,648 | 14.1million | \$15.7 million | \$12.4 million |
| | Concept | Environmental and sustainable Approach | Nature preserves (protection of urban nature) | Regenerative Design through natural processes, Low-Maintenance Urban Park Preservation & Restoration, | Showcase sustainable technologies for the 2010 Shanghai World Expo, | Creating a stormwater quality improvement project |
| Environmental Aspects | Climatic Aspects | Air Quality | Sequesters an estimated 2,800 metric tons (6.2 million lbs) of CO ₂ annually in the trees of the park, equivalent to removing 555 passenger vehicles from the road each year. | Sequesters an estimated 539 tons of carbon in the trees and plants on the site, a service valued at approximately \$7,200. The carbon fixation of reed wetland is 13.32t/ha, therefore it is estimated that 12tons of carbon are sequestered in 8,997m ² reed. | Sequesters an estimated 242 tons of carbon annually in park's extensive wetlands, perennial plantings, and trees. | Sequesters an estimated 1.82 tons of atmospheric carbon annually in trees, the carbon equivalent of driving a single passenger vehicle almost 4,000 miles. Reduces localized heat island effect by 8.5°F. Removal of 87.5% of the heat-producing surfaces which had previously been located onsite. |
| | | Urban Micro-Climate | | | | |
| | | Carbon Footprint | | | | |
| | Sustainability | Energy | No Data Available | No Data Available | No Data Available | Generates 8,081 kWh of energy annually, or 66% of the site's total energy use. |
| | | Materials | <ul style="list-style-type: none"> The Bio-remediation Facility is all built with natural materials. Re-establishing the natural landscape in the desert tablelands A series of natural stone weirs were built | <ul style="list-style-type: none"> Saved \$47.2 million in material costs by reusing 6 million cubic meters of coal ash to produce foundations and bricks used in park construction. Saved \$369,000 in construction costs by recycling 133,820 trunks of dead trees to form an embankment structure to prevent erosion along the lakeshore. | <ul style="list-style-type: none"> Saved approximately \$25,500 in lumber costs by reusing 84.5 cubic meters of old railroad ties in the construction of the observation platforms and bridges. | Reclaimed steel from the site was used to create the steel arbor and shade structure, the 'hanging garden', and architectural details, invoking the site's industrial past. Reused 37 tons of steel and roughly 34,000 post-industrial bricks found on the site |
| | | Solid/ Liquid Wastes | 17.7 million cu ft of industrial/ municipal waste Removed | 450 metric tons of rubbish in Nanhu area were reclaimed and used to create a 50-meter-high hill, offering 130,000 square meters of green space. | During construction, waste was minimized and recycled wherever possible. Inert onsite waste reclaimed as fill material to create topography | Reusing steel and bricks found on the site to create the hanging gardens, steel arbors and shade structures, paved areas, and architectural details, saved an estimated \$17,300 in material costs. |
| | | Soil | No soil samples were available to confirm soil quality | No Data Available | Improves soil alkalinity in dry ponds and water quality in the wet ponds. Soil pH dropped from 7.7 to around 7.2 and water pH levels dropped from 7.4. to 7 or less | Removes an estimated 100% of oil and grease, 75% of bacteria, 96% of total suspended solids, 41% of nitrate, and 34% of phosphorous from stormwater runoff. |

| | | | | | | | |
|------------------|---------------------------------|--------------------|---|--|---|--|--|
| | Biodiversity; Habitat Diversity | Flora (Vegetation) | Re-naturalizing 115 acres of indigenous plant species and 35 acres with seeded native grasses and perennials. Expanded by an additional 47 acres between 2010 and 2015 | More than 620,000 trees and shrubs of about 100 species are planted in the park, creating various wildlife habitats including woodland, bosque, grassland, and wetland. | <ul style="list-style-type: none"> Increased the habitat value of the site, with the number of herbaceous plants greatly increasing, from 5 to 96 species Tree species increased from 2 to 50. | Increased the biodiversity of the site dramatically, with 93 species of plants | 88 trees planted along the wetland's periphery |
| | | Fauna | 15 bird species, 9 fish species, 3 mollusk species, 2 amphibian species, 3 reptile species | Provides habitats for 6 fish, 4 reptile, 3 amphibian, 2 mammal, and 81 bird species observed on the site. Of these, 7 are nationally protected wildlife species. | Species increased to 6, accounting for ducks, geese, foxes, hedgehogs, rats and weasels. | over 200 species of animals observed. | <ul style="list-style-type: none"> Serves as habitat for numerous species of wildlife, particularly birds Reported sightings of 9 different species, Recorded 35 different species, Making it an urban birding hotspot in LA area |
| | Water | Water Reused | <ul style="list-style-type: none"> 350,000 m3 of wastewater cleaned per day (2010) 1,200,000 m3 of wastewater cleaned per day (By 2025) Reduces potable water consumption by 92.5 million gallons per day | Reduces potable water consumption by 29,200,000 cubic meters (7.7 billion gallons) annually, equivalent to 11,680 Olympic-sized swimming pools, by importing reclaimed water from a nearby sewage treatment plant. The reclaimed water is further treated in a series of constructed wetlands and used for water body recharge and irrigation in the park, saving about \$15.4 million per year. | Water fluctuates in different space and time, and it nurtures different species and purify the saline soil Water pH levels dropped from 7.4. to 7 or less. | Cleans up to 634,000 gallons of polluted river water daily, improving the water's quality from Grade V (unsuitable for human contact) to Grade II (suitable for landscape irrigation) using only biological processes. | Treats up to 14,000 gallons of stormwater runoff from the 525-acre watershed per day. This is sufficient capacity to treat all runoff during the dry season. |
| | | Water Quality | Removes an average of 33% of phosphorous, 13.5% of nitrogen, 89% of fecal coliforms, 79% of total coliforms, and 94% of total suspended solids from urban wastewater. After treatment, fecal coliform levels in the water are low enough to allow for occasional human contact. | | | | Irrigation Requires less than 35% of the irrigation for wetland plants than a traditional turf area would require during months of lowest water flow, which translates to between 0.4 - 0.5 inches/week, as compared to 1.5 inches per week. |
| Social Aspects | | Social Benefits | Attracts 200,000 visitors per week, re-establishing the social, cultural, and recreational significance of the wadi for Riyadh residents. Generates no offensive odors due to an average dissolved oxygen concentration of 6.54 at the facility's outlet. | A 15-minute walking distance park access for adjacent 10,000 residents | <ul style="list-style-type: none"> Noise level drops from 70dB outdoors to 50dB inside. Green-space access for 20,000 near residents, with under 15-minutes-walk. In addition to a total of 26 serving bus lines. 350,000 annual visitors from neighboring areas. Educational experience to around 500 kids of local schools, more pupils engaging in summer vacation programs. Ecological awareness | During the 2010 Shanghai World Expo, about 590,500 visitors were provided with recreational and educational options. Residents of the city and visitors from all around China and the world continue to benefit from the park | <ul style="list-style-type: none"> Per capita Park acreage increased by 11%, from 0.54 acres to 0.6 acres per 1,000 persons. The nearby communities' median household income is \$29,074, only 58% of city's median. Community engagement in various activities, Historical structure was saved, with plans to utilize it in Phase II. |
| Economic Aspects | | Economic Benefits | Saves around \$27 million per day, the cost of 253,000 barrels of oil that would be required for desalinization and reduces reliance on seawater as a water source. | <ul style="list-style-type: none"> Material costs saving of \$47.2 million through utilization of 6 million m3 of coal ash in production of bricks and foundations for construction of the park. Construction costs saving of \$369,000 through reusing 133,820 dead tree trunks to make an embankment construction for lakefront erosion prevention. Earns \$157,300 in annual revenue through recreative and facility leasing fees. | <ul style="list-style-type: none"> Minimal maintenance save over \$19,000 in annual maintenance costs Reusing 84.5m³ of old railroad ties saved around \$25,500 timber expenses. Water quality is maintained by the ponds' design and the employment of native vegetation, with a limited amount of water treatment chemicals. Saves over \$5,000 per year. when compared to the cost of water treatment chemicals in a regular park, this | <ul style="list-style-type: none"> Water treatment using natural processes value of about \$131-145,000/ year The Expo Park uses 264,000 gallons of the cleaned water by wetland saving \$116,800 per year in water expenses. Reusing 37 tons of steel and nearly 34,000 post-industrial bricks discovered on the site reduced trash and saved an estimated \$17,300. | <ul style="list-style-type: none"> Adds \$243.43 /ft² gain in house value for properties within 3*3 block square centered on the park, compared to \$217.14 for homes beyond this area and within a 5*5-block square centered on the park. The cost /ft² of the closer home residences has increased by 12%. Produces 8,081 kWh of energy each year, accounting for 66% of the site's total energy use. This saves \$1,700 in energy bills annually. |

Chapter 5: Proposed CWP Assessment Tool

Introduction

The study aims to reach a proactive framework to assess the wetland park's performance towards achieving sustainability. Different Metrics are described that can be used for each aspect and sub-category to evaluate each park according to the data available and to the various use of each wetland park. The set of Metrics evaluates the wetland change and sustainability assessment based on landscape indicator analysis.

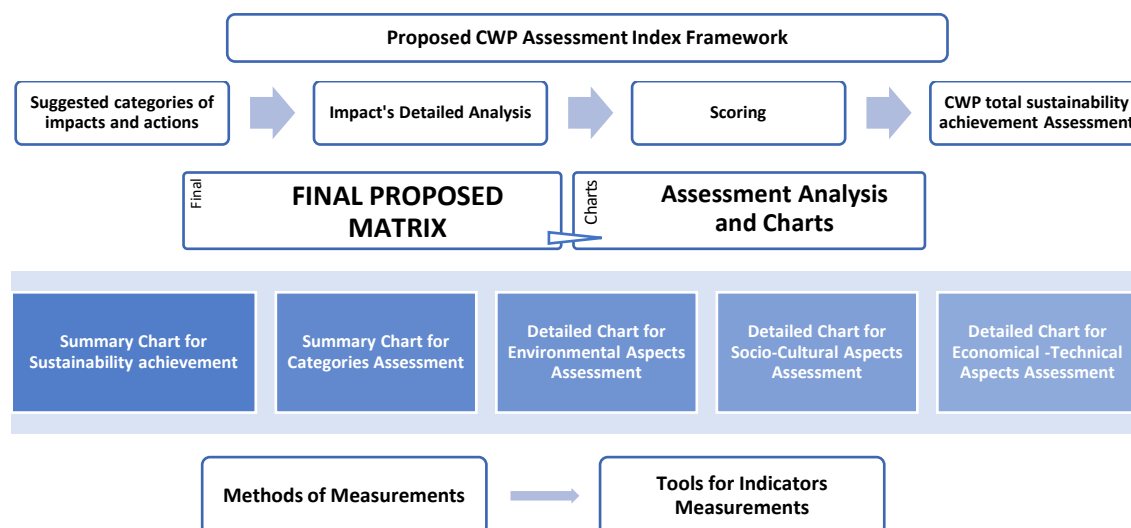


Fig. (142) Chapter 5, Methodology and structure, Source: Author

5.1 Proposed CWP Assessment Index Framework:

The proposed Constructed Wetland Parks Assessment Index include a detailed matrix, a summarized sustainability performance charts for the total park performance and construction and operation phases, a summarized chart for categories assessment analysis and three detailed charts for each of the sustainability pillars. The assessor is required only to enter the name of the project, the location, and his own assessment score for both the construction and operation phases in the Matrix sheet. To help the assessor in the evaluation and scoring of each impact, suggestions of various methods and tools of measurements are explained (See point: 3.4.3 Methods of Measurements and 3.4.4 Tools for Methods Measurements)

Each impact should be assessed for the Magnitude, Significance, Probability and Duration of the factor. The assessor's assessment should cover each impacts' factors according to the rating system. All the equations and assessment analysis are then calculated automatically and presented in charts showing the assessed CW Park's achieved score compared with the total score that could be achieved. The proposed Matrix will automatically calculate the Impact value relevance (**IV**), total Environmental Impact Value (**EIV**), the Ratio of Impact Factor (**R**) and the IV Weight Relevance Value (**IVWR**) according to the discussed equations, and the percentage achieved for each factor for better understanding of the CW Park's performance and hence, helping in the decision making.

5.1.1 Suggested Matrix's main categories of impacts and actions

Table (12) Suggested Impacts and actions categories' Matrix, Source: Author

| Impacts \ Activities | | Project Activities | |
|--------------------------------------|------------------|---|-----------------|
| | | Construction Phase | Operation Phase |
| Category | Impact Factors | | |
| Environmental Impact Factors | Climatic Aspects | Air Quality | |
| | | Urban Micro-Climate | |
| | | Carbon Footprint | |
| | | Noise | |
| | Sustainability | Energy | |
| | | Materials | |
| | | Solid/ Liquid Wastes | |
| | | Soil | |
| | Bio-diversity | Flora (Vegetation) | |
| | | Fauna | |
| | Water | Water Reused | |
| | | Water Quality | |
| Socio-Cultural Impact Factors | Community Values | Community Size Served | |
| | | Community Awareness | |
| | | Community Acceptance | |
| | Social Values | Education / Training | |
| | | Public Participation | |
| | | Increased Recreational & Social Activities | |
| | | Added Social & Connectivity Values | |
| | Aesthetic Values | Visual Aesthetic Value | |
| | | Odor Reduction Efficiency | |
| Economical -Technical Impact Factors | Economic Values | Catalyzing Economic Development | |
| | | Land Use Value | |
| | | Economic Savings | |
| | | Potentials of Economic Revenue | |
| | Technical Values | Construction Process Flexibility | |
| | | Operation & Maintenance Process Flexibility | |
| | | Future Potential for Upgrading | |

5.1.2 Detailed analysis for each impact, represented in a 4-division cell:

Each Impact factor (IF) is evaluated for each phase separately

- (M) Magnitude of the factor's impact (on a scale from 0 to 5)
 (S) Significance of the factor's impact (on a scale from 0 to 5)
 (P) Probability of the factor's impact (on a scale from 0 to 5)
 (D) Duration of the factor's impact (on a scale 1 to 2)

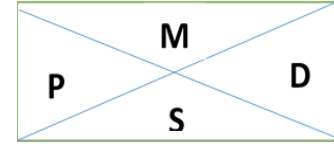


Fig. (143) Cell of proposed Matrix, Source: Author

Impact factors (IF) are evaluated on a scale from 0 to 5 for each phase separately. The **Impact value relevance (IV)** for each factor is then calculated by multiplying the 4 measurements together. The Impact Value Relevance, total Environmental Impact Value (EIV), the Ratio of Impact Factor (R) and the IV Weight Relevance Value (IVWR) are calculated from Equations (1) to (4) respectively:

$$\text{Impact Value Relevance for each Factor (IV)} = M * S * P * D \quad \text{Equation (1)}$$

$$\text{Environmental Impact Value (EIV)} = \sum_{i=1}^n Mi * Si * Pi * Di \quad \text{Equation (2)}$$

$$\text{Ratio of Impact Factor from total (R)} = IV / EIV \quad \text{Equation (3)}$$

$$\text{The IV Weight Relevance Value (IVWR)} = R * FW \quad \text{Equation (4)}$$

FW is the Factor weight based on the questionnaire

5.1.3 Scoring

The scoring for each of the four evaluations is based on the following scales,

Impact Magnitude (M) is scored on a scale from 0 to 5, according to the following scale:

- 0 – No observable effect
- 1 – Low effect
- 2 – Tolerable effect
- 3 – Medium high effect
- 4 – High effect
- 5 – Very high effect (devastation)

In addition to the standard form of the Leopold matrix, the following criteria have also been used:

Impact Significance (S) is scored on a scale from 0 to 5, according to the following scale:

- 0 – No impact
- 1 – Significance 1 – 20%
- 2 – Significance 21 – 40%
- 3 – Significance 41 – 60%
- 4 – Significance 61 – 80%
- 5 – Significance 81 -100%

Impact Probability (P) is scored on a scale from 0 to 5, according to the following scale:

- 0 – Impact is less possible (probability less than 5%)
- 1 – Impact is possible (probability of 5- less than 25%)
- 2 – Impact is Highly possible (probability of 25- less than 50%)
- 3 – Impact is probable (probability of 50- less than 75%)
- 4 – Impact is Highly probable (probability of 75- less than 100%)
- 5 – Impact is certain (100% probability)

Impact Duration (D) is scored on a scale from 1 to 2, according to the following scale:

- 1 – Short-term/ Occasional/ Temporary
- 2 – Long-term/ Permanent

5.1.4 Assessment of the total sustainability achievement of the CWP

To achieve a logical indicative total sustainability achievement of the CWP, each of its two phases; construction and operation phase, should be assessed according to their impact weight in the life cycle of the CWP. CW for wastewater treatment's lifespan extends according to its wastewater loadings and so far, have shown lifespan of more than 20 years without remarkable loss of efficiency as described in the literature review (*Please check chapter 2, 2.3 CW for wastewater treatment*) (Davis, L., 1995) while the construction phase normally extend for an average between 1 to 3 years, the operation phase could be extended from 20-30 years. Thus, the impact weight of the two phases could be given as follow:

$$\text{Phase weight} = \frac{\text{Phase Lifespan}}{\text{Construction Phase Lifespan} + \text{Operation Phase Lifespan}}$$

Where:

$$\begin{aligned} \text{Construction Phase weight} &= \frac{\text{Construction Phase Lifespan}}{\text{Average Construction Phase Lifespan} + \text{Average Operation Phase Lifespan}} \\ &= \frac{2}{2 + 25} = 0.074 \end{aligned}$$

$$\begin{aligned} \text{Operation Phase weight} &= \frac{\text{Operation Phase Lifespan}}{\text{Average Construction Phase Lifespan} + \text{Average Operation Phase Lifespan}} \\ &= \frac{25}{2 + 25} = 0.926 \end{aligned}$$

5.2 Final proposed Matrix

Table (13) Proposed Matrix, Source: Author

| Impacts \ Activities | | Project's Activities | | | | | | | | | | | | |
|------------------------------|---------------------|-------------------------------|------------------------------------|-------------------------------|--------------------------------|----------------------------|---------------------|----------------------------|------------------------------------|-------------------------------|--------------------------------|----------------------------|---------------------|-------|
| | | Construction Phase | | | | | | Operation Phase | | | | | | |
| | | Construction Phase Assessment | IV= Impact Value relevance S*M*P*D | Impact Factor Ratio R= IV/EIV | Weight Based on Question naire | IV Weight Relevance (IVWR) | Percentage Achieved | Operation Phase Assessment | IV= Impact Value relevance S*M*P*D | Impact Factor Ratio R= IV/EIV | Weight Based on Question naire | IV Weight Relevance (IVWR) | Percentage Achieved | |
| Category | Impact Factors (IF) | | | | | | | | | | | | | |
| Environmental Impact Factors | Climatic Aspects | Air Quality | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.9 | 0 | 0.00% |
| | | Urban Micro-Climate | | 0 | 0 | 0.7 | 0 | 0.00% | | 0 | 0 | 0.9 | 0 | 0.00% |
| | | Carbon Footprint | | 0 | 0 | 0.7 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | | Noise | | 0 | 0 | 0.7 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | Sustainability | Energy | | 0 | 0 | 0.7 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | | Materials | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | | Solid/ Liquid Wastes | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | | Soil | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | Biodiversity | Flora (Vegetation) | | 0 | 0 | 0.9 | 0 | 0.00% | | 0 | 0 | 0.9 | 0 | 0.00% |
| | | Fauna | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | Water | Water Reused | | 0 | 0 | 0.9 | 0 | 0.00% | | 0 | 0 | 0.9 | 0 | 0.00% |
| | | Water Quality | | 0 | 0 | 0.9 | 0 | 0.00% | | 0 | 0 | 0.9 | 0 | 0.00% |

| Impacts \ Activities | | | Project Activities | | | | | | | | | | | |
|--------------------------------|--------------------------------------|---|---------------------------------|------------------------------------|-------------------------------|--------------------------------|----------------------------|---------------------|----------------------------|------------------------------------|-------------------------------|--------------------------------|----------------------------|---------------------|
| | | | Construction Phase | | | | | | Operation Phase | | | | | |
| | | | Construction Phase Assessment | IV= Impact Value relevance S*M*P*D | Impact Factor Ratio R= IV/EIV | Weight Based on Question naire | IV Weight Relevance (IVWR) | Percentage Achieved | Operation Phase Assessment | IV= Impact Value relevance S*M*P*D | Impact Factor Ratio R= IV/EIV | Weight Based on Question naire | IV Weight Relevance (IVWR) | Percentage Achieved |
| Category | Impact Factors (IF) | | | | | | | | | | | | | |
| Socio-Cultural Impact Factors | Community Values | Community Size Served | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | | Community Awareness | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | | Community Acceptance | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | Social Values | Education / Training | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | | Public Participation | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | | Increased Recreational & Social Activities | | 0 | 0 | 0.9 | 0 | 0.00% | | 0 | 0 | 0.9 | 0 | 0.00% |
| | | Added Social, Connectivity & Safety Values | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | Aesthetic Values | Visual Aesthetic Value | | 0 | 0 | 0.9 | 0 | 0.00% | | 0 | 0 | 0.9 | 0 | 0.00% |
| | | Odor Reduction Efficiency | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | Economical -Technical Impact Factors | Economic Values | Catalyzing Economic Development | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 |
| Land Use Value | | | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| Economic Savings | | | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| Potentials of Economic Revenue | | | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| Technical Values | | Construction process Flexibility | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | | Operation and Maintenance Process Flexibility | | 0 | 0 | 0.8 | 0 | 0.00% | | 0 | 0 | 0.8 | 0 | 0.00% |
| | | Future Potential for Upgrading | | 0 | 0 | 0.9 | 0 | 0.00% | | 0 | 0 | 0.9 | 0 | 0.00% |

5.3 Assessment Analysis and Charts

From the CWP Assessment Matrix, a detailed table is calculated representing the assessed CW Park's achieved score compared with the maximum score that could be achieved. The assessment is simplified through easy-to-understand visual charts for a clear understanding, evaluation and assessment of the chances for improvements and to identify which factors needs to be further improved and which are of positive impacts on the environment.

5.3.1 Summary Chart for Sustainability achievement

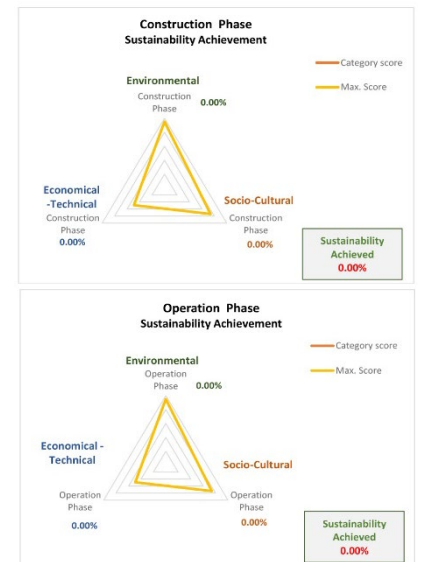
Fig. (144) Park's Sustainability achievement Chart, Source: Author

Project Title:
Project Type:
Location:
Climatic Zone:
Hardiness Zone:
Assessment Author:

| nr. | Category | Category Total Score | Max Score | Sustainability Weight from Questionnaire | Sustainability | |
|-------------------------|---------------------------------------|----------------------|-----------|--|---------------------------------------|--------------------------------------|
| | | | | | Achieved Sustainability Score from 10 | Maximum Sustainability Score from 10 |
| 1 | Environmental Impact Factors | 0 | 2702 | 0.4234 | 0.00 | 4.23 |
| 2 | Socio-Cultural Impact Factors | 0 | 1988 | 0.2947 | 0.00 | 2.95 |
| 3 | Economical - Technical Impact Factors | 0 | 1317 | 0.2819 | 0.00 | 2.82 |
| Total Impact Assessment | | | | 1.00 | 0.00 | 10 |



| nr. | Category | Category score | Max. Score | % | Phase Weight | Category Total Score | Max Score | Percentage Achieved |
|--|--------------------|----------------|------------|-------|--------------|----------------------|-----------|---------------------|
| 1 | Construction Phase | 0 | 2375 | 0.00% | 0.074 | 0 | 2702 | 0.00% |
| 2 | Operation Phase | 0 | 2525 | 0.00% | 0.926 | | | |
| 3 | Construction Phase | 0 | 1850 | 0.00% | 0.074 | 0 | 1988 | 0.00% |
| 4 | Operation Phase | 0 | 1850 | 0.00% | 0.926 | | | |
| 5 | Construction Phase | 0 | 1225 | 0.00% | 0.074 | 0 | 1317 | 0.00% |
| 6 | Operation Phase | 0 | 1225 | 0.00% | 0.926 | | | |
| Total Sustainability Achievement in Construction Phase | | | | | | | | 0.00% |
| Total Sustainability Achievement in Operation Phase | | | | | | | | 0.00% |

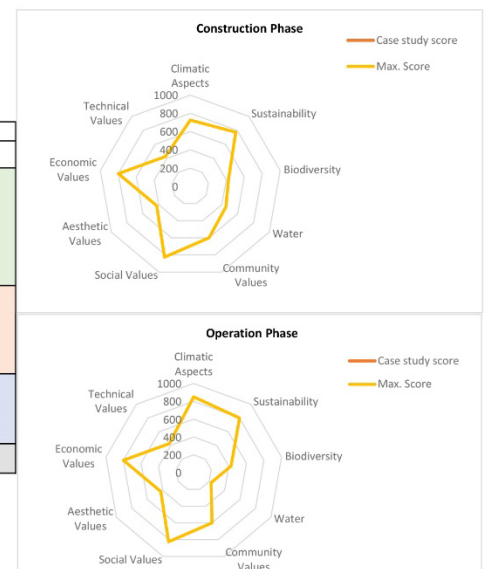


5.3.2 Summary Chart for Categories Assessment

Fig. (145) Park's Categories Assessment Chart, Source: Author

Project Title:
Project Type:
Location:
Climatic Zone:
Hardiness Zone:
Assessment Author:

| nr. | Category | Construction Phase | | | Category Total Score | Max Score | Percentage Achieved | Operation Phase | | | Category Total Score | Max Score | Percentage Achieved |
|-------------------------|------------------|--------------------|------------|-------|----------------------|-----------|---------------------|------------------|------------|-------|----------------------|-----------|---------------------|
| | | Case study score | Max. Score | % | | | | Case study score | Max. Score | % | | | |
| 1 | Climatic Aspects | 0 | 725 | 0.00% | 0 | 2375 | 0.00% | 0 | 850 | 0.00% | 0 | 2300 | 0.00% |
| 2 | Sustainability | 0 | 775 | 0.00% | | | | 0 | 800 | 0.00% | | | |
| 3 | Biodiversity | 0 | 425 | 0.00% | | | | 0 | 425 | 0.00% | | | |
| 4 | Water | 0 | 450 | 0.00% | | | | 0 | 225 | 0.00% | | | |
| 5 | Community Values | 0 | 600 | 0.00% | 0 | 1850 | 0.00% | 0 | 600 | 0.00% | 0 | 1850 | 0.00% |
| 6 | Social Values | 0 | 825 | 0.00% | | | | 0 | 825 | 0.00% | | | |
| 7 | Aesthetic Values | 0 | 425 | 0.00% | | | | 0 | 425 | 0.00% | | | |
| 8 | Economic Values | 0 | 800 | 0.00% | 0 | 1225 | 0.00% | 0 | 800 | 0.00% | 0 | 1225 | 0.00% |
| 9 | Technical Values | 0 | 425 | 0.00% | | | | 0 | 425 | 0.00% | | | |
| Total Impact Assessment | | | | | 0 | 5450 | 0.00% | | | | 0 | 5375 | 0.00% |



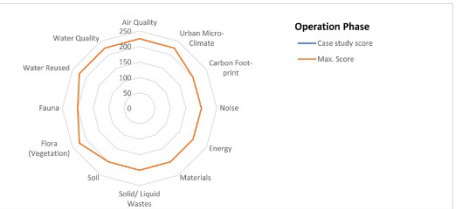
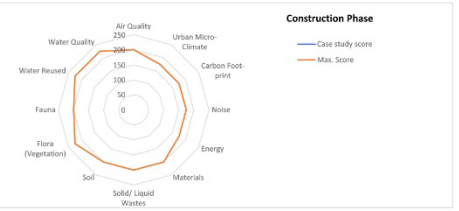
5.3.3 Detailed Chart for Environmental Aspects Assessment

Fig. (146) Park's Environmental Aspects Assessment Chart, Source: Author

Project Title:
Project Type:
Location:
Climatic Zone:
Hardiness Zone:
Assessment Author:

| | | | Construction Phase | | | | | | | | | | | | |
|---------------------------|----------------------|---------------------|--------------------|-------------------|------------------|---------------|-------------------------------|------------------|------------------|------------|-------|----------------------------|-----------|---------------------|-------|
| Nr. | Category | Impact Factor | M Magnitude | S Significance | P Probability | D Duration | IV= Impact Value Relevance | Factor Weight | Case study score | Max. Score | % | Total Category Score | Max Score | Percentage Achieved | |
| 1 | Climatic Aspects | Air Quality | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | 0 | 725 | 0.00% | |
| 2 | | Urban Micro-Climate | 0 | 0 | 0 | 0 | 0 | 0.7 | 0 | 175 | 0.00% | | | | |
| 3 | | Carbon Foot-print | 0 | 0 | 0 | 0 | 0 | 0.7 | 0 | 175 | 0.00% | | | | |
| 4 | | Sustainability | Noise | 0 | 0 | 0 | 0 | 0 | 0.7 | 0 | 175 | 0.00% | 0 | 775 | 0.00% |
| 5 | | | Energy | 0 | 0 | 0 | 0 | 0 | 0.7 | 0 | 175 | 0.00% | | | |
| 6 | | | Materials | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | | | |
| 7 | Solid/ Liquid Wastes | | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | | | | |
| 8 | Biodiversity | Soil | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | 0 | 425 | 0.00% | |
| 9 | | Flora (Vegetation) | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 225 | 0.00% | | | | |
| 10 | | Fauna | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | | | | |
| 11 | | Water Reused | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 225 | 0.00% | | | | |
| 12 | Water | Water Quality | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 225 | 0.00% | 0 | 450 | 0.00% | |
| Total Environmental Value | | | | | | | | | 0 | 1075 | | 0 | 2375 | 0.00% | |

| | | | Operation Phase | | | | | | | | | | | | |
|---------------------------|----------------------|---------------------|-----------------|-------------------|------------------|---------------|-------------------------------|------------------|------------------|------------|-------|----------------------------|-----------|---------------------|-------|
| Nr. | Category | Impact Factor | M Magnitude | S Significance | P Probability | D Duration | IV= Impact Value Relevance | Factor Weight | Case study score | Max. Score | % | Total Category Score | Max Score | Percentage Achieved | |
| 1 | Climatic Aspects | Air Quality | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 225 | 0.00% | 0 | 850 | 0.00% | |
| 2 | | Urban Micro-Climate | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 225 | 0.00% | | | | |
| 3 | | Carbon Foot-print | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | | | | |
| 4 | | Sustainability | Noise | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | 0 | 800 | 0.00% |
| 5 | | | Energy | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | | | |
| 6 | | | Materials | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | | | |
| 7 | Solid/ Liquid Wastes | | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | | | | |
| 8 | Biodiversity | Soil | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | 0 | 425 | 0.00% | |
| 9 | | Flora (Vegetation) | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 225 | 0.00% | | | | |
| 10 | | Fauna | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | | | | |
| 11 | | Water Reused | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 225 | 0.00% | | | | |
| 12 | Water | Water Quality | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 225 | 0.00% | 0 | 450 | 0.00% | |
| Total Environmental Value | | | | | | | | | 0 | 1050 | 1050 | 0 | 2525 | 0.00% | |



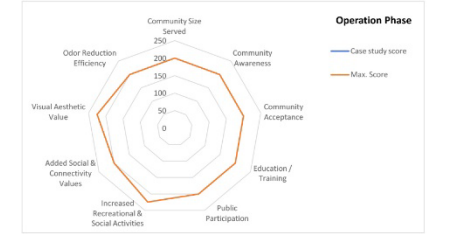
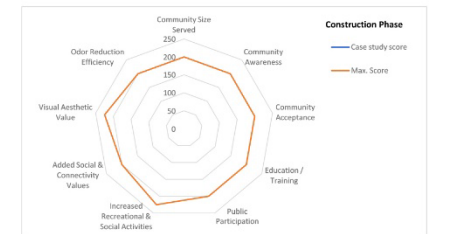
5.3.4 Detailed Chart for Socio-Cultural Aspects Assessment

Fig. (147) Park's Socio-Cultural Aspects Assessment Chart, Source: Author

Project Title:
Project Type:
Location:
Climatic Zone:
Hardiness Zone:
Assessment Author:

| Socio-Cultural Impact Factors | | | Construction Phase | | | | | | | | | | | | |
|-------------------------------|-------------------------------|------------------------------------|--|----------------|---------------|------------|----------------------------|---------------|------------------|------------|-----|----------------------|-----------|---------------------|-------|
| Nr. | Category | Impact Factor | M Magnitude | S Significance | P Probability | D Duration | IV= Impact Value relevance | Factor Weight | Case study score | Max. Score | % | Total Category Score | Max Score | Percentage Achieved | |
| 13 | Socio-Cultural Impact Factors | Community Size Served | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0 | 0 | 600 | 0.00% | |
| 14 | | Community Awareness | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0 | | | | |
| 15 | | Community Acceptance | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0 | | | | |
| 16 | | Social Values | Education / Training | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0 | 0 | 825 | 0.00% |
| 17 | | | Public Participation | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0 | | | |
| 18 | | | Increased Recreational & Social Activities | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 225 | 0 | | | |
| 19 | Aesthetic Values | Added Social & Connectivity Values | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0 | 0 | 425 | 0.00% | |
| 20 | | Visual Aesthetic Value | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 225 | 0 | | | | |
| 21 | | Odor Reduction Efficiency | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0 | | | | |
| Total Socio-Cultural Value | | | | | | | | | 0 | 1850 | 0 | | | | 1850 |

| | | | Operation Phase | | | | | | | | | | | | |
|----------------------------|-------------------------------|------------------------------------|--|----------------|---------------|------------|----------------------------|---------------|------------------|------------|-----|----------------------|-----------|---------------------|-------|
| Nr. | Category | Impact Factor | M Magnitude | S Significance | P Probability | D Duration | IV= Impact Value relevance | Factor Weight | Case study score | Max. Score | % | Total Category Score | Max Score | Percentage Achieved | |
| 13 | Socio-Cultural Impact Factors | Community Size Served | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0 | 0 | 600 | 0.00% | |
| 14 | | Community Awareness | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0 | | | | |
| 15 | | Community Acceptance | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0 | | | | |
| 16 | | Social Values | Education / Training | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0 | 0 | 825 | 0.00% |
| 17 | | | Public Participation | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0 | | | |
| 18 | | | Increased Recreational & Social Activities | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 225 | 0 | | | |
| 19 | Aesthetic Values | Added Social & Connectivity Values | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0 | 0 | 425 | 0.00% | |
| 20 | | Visual Aesthetic Value | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 225 | 0 | | | | |
| 21 | | Odor Reduction Efficiency | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0 | | | | |
| Total Socio-Cultural Value | | | | | | | | | 0 | 1850 | 0 | | | | 1850 |

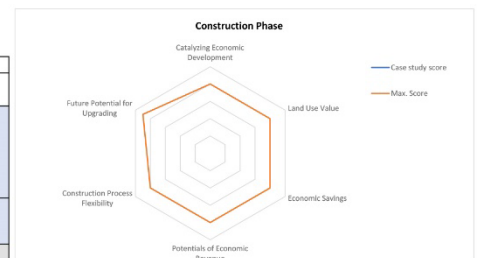


5.3.5 Detailed Chart for Economical -Technical Aspects Assessment

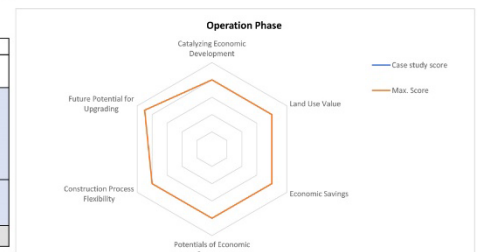
Fig. (148) Park's Economical -Technical Aspects Assessment Chart, Source: Author

Project Title:
Project Type:
Location:
Climatic Zone:
Hardiness Zone:
Assessment Author:

| Assessment Matrix: | | | Construction Phase | | | | | | | | | | | | |
|-----------------------------------|-------------------------------------|---------------------------------|----------------------------------|----------------|---------------|------------|----------------------------|---------------|------------------|------------|-------|----------------------|-----------|---------------------|-------|
| Nr. | Category | Impact Factor | M Magnitude | S Significance | P Probability | D Duration | IV= Impact Value relevance | Factor Weight | Case study score | Max. Score | % | Total Category Score | Max Score | Percentage Achieved | |
| 22 | Economic / Technical Impact Factors | Catalyzing Economic Development | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | 0 | 800 | 0.00% | |
| 23 | | Land Use Value | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | | | | |
| 24 | | Economic Savings | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | | | | |
| 25 | | Technical Values | Potentials of Economic Revenue | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | 0 | 425 | 0.00% |
| 26 | | | Construction Process Flexibility | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | | | |
| 27 | | | Future Potential for Upgrading | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 225 | 0.00% | | | |
| Total Economical -Technical Value | | | | | | | | | 0 | 1225 | | 0 | 1225 | 0.00% | |



| | | | Operation Phase | | | | | | | | | | | |
|-----------------------------------|-------------------------------------|---|-----------------|-------------------|------------------|---------------|-----------------------------------|------------------|------------------|------------|-------|----------------------------|-----------|------------------------|
| Nr. | Category | Impact Factor | M Magnitude | S Significance | P Probability | D Duration | IV=I Impact Value relevance | Factor Weight | Case study score | Max. Score | % | Total Category Score | Max Score | Percentage Achieved |
| 22 | Economic - Technical Impact Factors | Catalyzing Economic Development | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | 0 | 800 | 0.00% |
| 23 | | Land Use Value | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | | | |
| 24 | | Economic Savings | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | | | |
| 25 | | Potentials of Economic Revenue | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | 0 | 425 | 0.00% |
| 26 | | Operation and Maintenance Process Flexibility | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 200 | 0.00% | | | |
| 27 | | Future Potential for Upgrading | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 225 | 0.00% | | | |
| Total Economical -Technical Value | | | | | | | | | 0 | 1225 | | 0 | 1225 | 0.00% |



5.4 Methods of Measurements

To assess the sustainability impact of the CW Parks, a clear understanding of the factor's performance is required. A set of measuring tools and applications were studied to select the best measuring tool that best fits each park's available data. This will help the assessor in quantifying the score for each impact factor. The following table shows the adopted sustainability indicators for measuring wetland impact and the different methods and tools that can be used for assessment. This Thesis suggest tools and metrics for the three sustainability indicators (Environmental, Social and Economic Indicators) but the case studies analysis will focus only on the Environmental Indicators and give a brief assessment on the social and economic indicators.

For each aspect or indicator, potential metrics were selected according to the US Environmental Protection Agency guide, Landscape Architecture Foundation Evaluating Landscape Performance, 2018. (LAF, 2018) The metrics were suggested by the Landscape Performance Organization and was analyzed to select the Metrics that best measure each indicator according to the available information for each park.

5.4.1 Environmental; Climatic Aspects

Table (14) Adopted environmental indicators for measuring wetland Climatic impact, Source: Author from LAF, 2018

| Category | Indicator | Sub-Indicators /Description | Type | POTENTIAL METRICS | Resources |
|-----------------------|------------------|---|--------------|--|--|
| Environmental Aspects | Climatic Aspects | Air Quality - Air quality: Improvement in air quality due to increased vegetation cover | Quantitative | Air Quality Reducing airborne pollutants Amount of air pollutants removed by woody vegetation (weight/year) Use the US Forest Service (USFS) i-Tree suite of tools to estimate air pollutant removal by trees and shrubs. Tool selection will depend on the scale of vegetation and desired accuracy. The desktop application i-Tree Eco gives hourly air quality improvement for O ₃ , NO ₂ , SO ₂ , CO, and PM ₁₀ . It can be used with data for individual trees, complete inventories, or random plot samples. The web-based i-Tree products use aerial imagery or data for individual trees to estimate air pollutant removal and avoidance (from reduced energy needs). These tools can also forecast future benefits based on projected tree growth over time. | USFS: i-Tree Applications US Environmental Protection Agency: Air Quality Index (AQI) |
| | | Urban Micro-Climate - Heat Island Effect: % of decrease in Heat Island Effect due to increased vegetation cover and water bodies | Quantitative | Temperature & Urban Heat Island Reducing localized temperatures and heat island impacts Reduction in air temperature (degrees or percent) Measure air temperatures throughout the site or in a particular area of interest. Compare them to the before condition or to air temperature readings taken in a conventionally designed space, possibly using weighted averages by area of each surface type. Air temperature is a better proxy for human comfort than surface temperature unless people come into direct contact with the surface, such as a bench or playground slide. Reduction in surface temperature (degrees or percent) Measure surface temperatures throughout the site or in a particular area of interest. Compare them to the before condition or to surface temperatures of a conventionally designed space, possibly using weighted averages by area of each surface type. Increase in reflectivity of materials (SRI) Reference project documents to determine the SRI values of roof, pavement, and other surface materials on the site. Compare them to the before condition or to SRI values of a conventionally designed space, possibly using weighted averages by area of each surface type. | Landscape Architecture Foundation Evaluating Landscape Performance, 2018 |
| | Climatic Aspects | Carbon Footprint -Carbon Footprint: amount of carbon dioxide and other GHG emissions associated with the wetland project compared to conventional treatment plant | Quantitative | Carbon Sequestration & Avoidance Capturing, storing, or preventing the release of carbon into the atmosphere <i>If carbon markets exist, carbon sequestration and avoidance can be converted to a monetary value.</i> Amount of atmospheric CO₂ sequestered (weight/year) Use the USFS i-Tree suite of tools to estimate carbon sequestration by trees and shrubs. The desktop application i-Tree Eco can be used with data for individual trees, complete inventories, or random plot samples. The web-based i-Tree products use aerial imagery or data for individual trees. These tools can also forecast future benefits based on projected tree growth over time. Use values from published research to estimate carbon sequestration for a particular ecosystem type, such as a wetland or prairie. Use USDA COMET-Farm or other farm carbon calculator to estimate carbon sequestration and emission reductions associated with conservation practices for cropland, pasture, and rangeland. Reduction in CO₂ emissions from maintenance or energy savings (weight/year) Use an estimator like the EPA Greenhouse Gas Equivalencies Calculator to convert energy savings to carbon dioxide equivalent. (See Energy Use.) Calculate the reduction in fuel use for mowing or other maintenance compared to fuel use prior to the project or on a conventional site. Use an estimator like the EPA Greenhouse Gas Equivalencies Calculator to convert to carbon dioxide equivalent. (See Operations & Maintenance Savings.) Reduction in CO₂ emissions from a reduction in vehicle miles traveled (weight/year) Estimate the reduction in trip frequency and distance for private automobiles. Use an estimator to convert this to a carbon dioxide equivalent. (See Transportation.) | USFS: i-Tree Applications USDA: COMET-Farm US Environmental Protection Agency (EPA): Greenhouse Gas Equivalencies Calculator |
| | | Noise Level: - Noise Level: Reducing noise level and Noise pollution through Landscape interventions, such as berms, walls, and techniques to lower vehicle speeds. | Quantitative | Noise Mitigation Reducing actual or perceived levels of undesirable sound Ambient noise levels (decibels) • Measure sound levels for an area of interest with a sound meter. • Reference documents from a previous sound study or modeling conducted for the site and report the change in noise levels. Perception of undesirable noise • Conduct a survey of users to determine their perceptions about noise in an area of interest. • Conduct a survey of site users or those who spend time in the vicinity to determine whether the design intervention changed their perceptions of noise. | Purdue University: Noise Sources and Their Effects Noise Meters, Inc.: Decibel Calculator |

5.4.2 Environmental; Sustainability Aspects

Table (15) Adopted environmental indicators for measuring wetland Sustainability impact,

Source: Author from LAF, 2018

| | | | | | | |
|-----------------------|----------------|-----------------------------|---|--------------|---|---|
| Environmental Aspects | Sustainability | Energy | <p>-Construction Energy Conservation: % of energy conserved during construction stage compared to conventional treatment plant</p> <p>- Operation Energy conservation: % of operational electrical energy conserved compared to conventional treatment operations measured over a specific temporal scale</p> | Quantitative | <p>Energy Use Reducing nonrenewable energy consumption</p> <p>Reduction in annual energy use (kWh/year or percent) Calculate the overall reduction in energy use by using utility bills to determine annual consumption. Compare it to consumption prior to the project or to that of a conventional site. This metric considers all elements that result in energy savings. Estimate the reduction in energy use associated with a green roof by using a green roof energy calculator like the GreenSave Calculator. Compare energy use of the installed system to that of a conventional roof. Estimate the reduction in energy use associated with efficient lighting or other landscape elements by using manufacturer information to compare energy consumption of the efficient system to that of a conventional system.</p> <p>Amount of reduction in annual energy use due to renewable sources (kWh/year or percent) Estimate the reduction in nonrenewable energy use associated with on-site generation by calculating the amount of energy needed and comparing it to the amount produced by solar panels, wind turbines, or other renewable sources.</p> <p>Annual cost savings from reduced energy use Convert the amount of energy saved to a monetary value using the local utility rate. Reduction in energy use can also be converted into carbon avoided. (See Carbon Sequestration & Avoidance.)</p> | <p>US Energy Information Administration: Average Retail Price of Electricity</p> <p>Green Roofs for Healthy Cities: GreenSave Calculator (members only)</p> |
| | | Materials | <p>-Recycled Materials: % of materials that is recycled or acquired from onsite materials</p> <p>-Hazardous Materials: % of hazardous materials and chemicals employed in water treatment process compared to conventional treatment processes</p> | Quantitative | <p>Reused & Recycled Materials Repurposing materials from the site or elsewhere</p> <p>Amount of material saved from waste disposal (weight or volume) Reference project documents to calculate the amount of material that was reused on the site instead of being sent to a landfill or other disposal site. This value can also be converted to carbon emission avoidance provided that all energy and transportation costs are accounted for.</p> <p>Amount of virgin material saved (weight or volume) Reference project documents to calculate the amount of virgin material that would have been needed in the absence of the reused or recycled materials. This metric is most applicable when recycled materials replace natural resources like timber, stone, or gravel.</p> <p>Cost savings for reusing materials on-site Estimate the cost savings from recycled or repurposed materials compared to purchasing new materials. This should consider labor, equipment, and transportation costs in addition to material costs. (See Construction Cost Savings.)</p> | <p>California Department of Housing and Community Development: Recycled Content Value Calculations Worksheet</p> <p>Roadway Fill Volume, Cost, and Weight Calculator</p> <p>US Green Building Council LEED Existing Buildings v3 (2009): Materials and Resources Calculator</p> |
| | | Solid/ Liquid Wastes | <p>- Quality/ Quantity of wastes: % of waste materials discharged during the treatment process</p> | Quantitative | <p>Waste Reduction Reducing the need for off-site waste disposal</p> <p>Amount of organic waste composted annually (weight or volume/year or percent of total) Consult waste management documents or maintenance records to determine or estimate the amount of vegetative material that is composted, chipped, or used as mulch on-site or collected for off-site composting or processing. Consult waste management documents to determine the amount of food waste that is composted on- or off-site.</p> <p>Amount of municipal solid waste recycled annually (weight or volume/year or percent of total) Consult waste management documents or maintenance records to determine or estimate the amount of material that is recycled. This is most applicable for sites with active recycling programs and collection facilities.</p> <p>Reduction in construction waste (weight or volume) Reference project documents to determine the amount of waste avoided compared to the waste from conventional design and construction processes. (See Reused & Recycled Materials and Construction Cost Savings.)</p> <p>Reduction in energy and greenhouse gas emissions from waste reduction (weight or unit of energy) Use the US Environmental Protection Agency (EPA) Waste Reduction Model (WARM) to estimate energy and emission reductions associated with waste reduction, recycling, and composting compared to a baseline scenario. (See Carbon Sequestration & Avoidance.)</p> | <p>EPA: Waste Reduction Model</p> <p>US Green Building Council LEED v4: Construction and Demolition Waste Calculator</p> |
| | | Soil | <p>- Quality/ Quantity of soil creation, preservation & restoration: % of fertile or restored soils</p> <p>-Reducing erosion and sedimentation</p> <p>-Improving soil health through nitrogen fixation, supporting nutrient cycling or pollution reduction</p> | Quantitative | <p>Soil Creation, Preservation & Restoration Remediating degraded soils and protecting undisturbed soils</p> <p>Increase in area of fertile or restored soils (area or percent of total site) Identify areas of fertile or restored soils through an environmental assessment report or project documents. Compare total area pre- and post-construction using site plans or aerial photographs.</p> <p>Improvement in soil health or fertility Determine increase in soil organic matter content, soil microbial biomass, and/or soil nutrients (percent of soil composition) by sending samples to be analyzed in soil lab. Determine change in soil pH levels by collecting samples and performing a soil pH test in the field or in soil lab. Determine reduction in levels of soil contaminants by sending samples to be analyzed in soil lab.</p> <p>Improvement in soil infiltration rate (change in rate) Measure infiltration time in the field using a single or double ring infiltrometer.</p> | <p>US Natural Resources Conservation Service (NRCS): Soil Health Assessment</p> <p>NRCS: Guidelines for Soil Quality Assessment in Conservation Planning</p> <p>American Society of Landscape Architects Landscape Architecture Technical Information Series: A Landscape Performance + Metrics Primer for Landscape Architects – Soils and Amendments (free for members)</p> |

5.4.3 Environmental; Biodiversity Aspects

Table (16) Adopted environmental indicators for measuring wetland Biodiversity impact,

Source: Author from LAF, 2018

| | | | | | | |
|-----------------------|---------------------------------|--------------------|---|--------------|---|---|
| Environmental Aspects | Biodiversity, Habitat Diversity | Flora (Vegetation) | - Number of Flora species introduced into the habitat | Quantitative | <p>Populations & Species Richness Supporting biodiversity</p> <p>Increase in species richness for a taxon of interest (number or percent change) Use data from field observations to calculate the change in the number of observed species over time. This may be done for a kingdom (such as plants), class (such as birds), order (such as primates), or other taxonomic group. Use eBird to find data on local bird sightings. A citizen science tool, this global online database allows local birders to collect observations on the presence and abundance of bird species and submit their data.</p> <p>Increase in abundance of a species of interest (number or percent change) Use data from field observations to calculate the change in the number of a species over time. Abundance can be measured by number of individuals observed, species presence, density, frequency, or biomass. Species of interest should be threatened, vulnerable, or indicator species.</p> | <p>Cornell Lab of Ornithology: eBird University of Idaho: Point Intercept Sampling Techniques University of Hawai'i: Measuring Abundance, Transects and Quadrats US Bureau of Land Management: Measuring and Monitoring Plant Populations</p> |
| | | Fauna | - Number of Fauna species introduced into the habitat | Quantitative | <p>Habitat Creation, Preservation, & Restoration Protecting and restoring functional ecosystems</p> <p>Area of critical habitat created, protected, or restored for species of interest (area or percent of total site) Reference project documents for areas of critical habitat identified on the site. Use aerial photographs, GIS analysis, or other tools to quantify spatial extent.</p> <p>Increase in continuous habitat area (area) Reference project documents to identify areas of habitat reconnected through the removal of physical barriers like roadways or culverts. Use GIS analysis or other tools to quantify spatial extent.</p> <p>Increase in habitat area for pollinators (area) Determine the plant species considered to be habitat for beneficial pollinators or other species of interest within the site's ecoregion. Reference project documents and plant lists to identify pollinator habitat areas on the project site. Use aerial photographs, GIS analysis, or other tools to quantify spatial extent.</p> <p>Habitat Quality Improving ecological integrity</p> <p>Increase in ecological integrity as measured by an established rating system (change in index value) Use the Floristic Quality Assessment (FQA) to determine an overall score for the site or designated habitat area. A list of observed plant species is needed. There are various regional versions of this method. This method is limited to regions that have developed plant coefficient lists, although lists can sometimes be adapted to other regions with limitations. Use the US Environmental Protection Agency (EPA) Rapid Bioassessment Protocols to conduct a habitat assessment and report the total score. This method applies to Wadeable streams and rivers. Use the US Fish and Wildlife Service (FWS) Habitat Evaluation Procedures. This method is useful for projects with a stated objective to optimize wildlife numbers for particular species. It requires detailed information on plant species and cover types. Time and budget constraints may limit the use of this method.</p> | <p>US Fish and Wildlife Service (FWS): Critical Habitat Mapper FWS: Find Endangered Species Xerces Society: Pollinator-Friendly Plant Lists</p> <p>Openlands: Universal FQA Calculator US Natural Resources Conservation Service: Sampling Vegetation Attributes EPA: Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers FWS: Habitat Evaluation Procedures</p> |

5.4.4 Environmental; Water treatment Aspects

Table (17) Adopted environmental indicators for measuring wetland water treatment impact,

Source: Author from LAF, 2018

| | | | | | |
|-------|---------------|---|--------------|---|--|
| Water | Water Reused | - Water Reused: % of water reused or reintroduced to the irrigation system. | Quantitative | <p>Water Body/Groundwater Recharge Replenishing aquifers and surface water bodies Area of recharge zone or shallow water table that is protected (area or percent of total recharge area) Reference project documents to identify recharge zone. Use aerial photographs, GIS analysis, or other tools to quantify spatial extent. Compare pre- and post-construction conditions.</p> <p>Increase in or maintenance of water level of a wetland, lake, pond, river, or stream (depth) Monitor water levels using a depth gauge, stream gauges, or a submersible level sensor.</p> <p>Increase in level of underground water table (depth) Monitor groundwater levels in a well with an electric sounding device, such as a coaxial water level meter or flat-tape water level meter. This method is applicable only if a well exists on the site.</p> <p>Water Conservation Reducing potable water use Reduction in potable water consumption (volume or percent) Calculate the overall reduction in water use by using water utility bills to determine annual consumption. Compare this to consumption prior to the project or to that of a conventional landscape. This method considers all elements that resulted in water savings. Estimate the reduction in water use associated with plant selection by comparing the amount of water needed to irrigate the sustainable landscape with the irrigation needs of a conventional landscape. Several resources exist to estimate water demand for different plant types. Estimate the reduction in water use associated with an efficient irrigation system or closed loop water recirculating feature by using manufacturer information to compare water consumption of the efficient system to that of a conventional system.</p> <p>Amount of water supplied by non-potable sources (volume or percent) Estimate conservation associated with rainwater harvesting or water reuse by calculating the annual amount of water needed and comparing it to the amount supplied by rainwater, greywater, and/or blackwater.</p> <p>Annual cost savings from reduced potable water consumption Convert the volume of potable water saved to a monetary value using the local utility rate.</p> | <p>US Department of Agriculture: Groundwater Recharge</p> <p>US Geological Survey (USGS): Groundwater Levels for the Nation Oregon Water Resources Department: How to Measure the Water Level in a Well</p> <p>US Environmental Protection Agency: Water Sense Water Budget Tool</p> <p>US Green Building Council LEED Existing Buildings v3 (2009): Water Efficient Landscaping University of California: Landscape Water Requirement Calculators</p> |
| | Water Quality | - Water quality: % of pathogens removed through the constructed wetland | Quantitative | <p>Water Quality Improving physical, chemical, and biological integrity of water Improvement in aquatic habitat Use the EPA Rapid Bioassessment Protocols to evaluate habitat condition and/or fish and macroinvertebrate indicator species in wadable streams and rivers. Conduct a study of benthic macroinvertebrates using a regional index of stream integrity. These are often available as part of volunteer stream monitoring efforts.</p> <p>Reduction in sediment load Measure turbidity (amount of light scattered by suspended particles) of a lake, pond, or stream using a turbidity meter, Secchi Disk, or transparency tube. Use grab samples to measure total suspended solids in the field or in a lab.</p> <p>Change in chemical or physical properties of interest Use grab samples to measure pH, temperature, dissolved oxygen, salinity, nutrients, heavy metals, or other properties of interest. Install sensors to monitor parameters like temperature, pH, conductivity (salinity), dissolved oxygen, and dissolved ions.</p> | <p>EPA: Monitoring and Assessing Water Quality</p> <p>EPA: Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers</p> <p>EPA: State-Specific Water Quality Standards</p> <p>EarthEcho International: EarthEcho Water Challenge</p> |

5.4.5 Socio-Cultural; Community Values Aspects

Table (18) Adopted Social indicators for measuring wetland Community value impact, Source: Author from references

| | | | | | |
|-------------------------------|-----------------------|--|--------------|---|---|
| Socio-Cultural Impact Factors | Community Size Served | Population served: No. of visitors during a specific time frame | Quantitative | <ul style="list-style-type: none"> • Use time-lapse photography • Direct observation of no. of visitors per time-period | Sources: - LAF, 2018 - Author |
| | Community Awareness | Community awareness of project target goals | Quantitative | <ul style="list-style-type: none"> • Interviews • Conduct a survey of users to determine the degree of awareness of the Park's target goals | Sources: - ASLA, 2018 - LAF, 2018 - Author |
| | Community Acceptance | Site use by target population -Degree of community acceptance of project | Quantitative | <ul style="list-style-type: none"> • Interviews • Conduct a survey of users to determine the degree of acceptance of the park in the community • Consult records that tracks use of the site. If the project was an improvement to an existing site, the change in visitation or use prior to and after the project can be reported. | Sources: - ASLA, 2018 - LAF, 2018 - Author |

5.4.6 Socio-Cultural; Social Values Aspects

Table (19) Adopted Social indicators for measuring wetland social value impact, Source: Author from references

| | | | | | |
|-------------------------------|--|---|--------------|--|--|
| Socio-Cultural Impact Factors | Education / Training | Increased educational values and training facilities (number/year) | Quantitative | <ul style="list-style-type: none"> • Conduct a survey on increased educational value or knowledge after visit • Number of attendees of educational / training events over a specific time scale | Sources: - LAF, 2018 - Author |
| | Public Participation | Level of community / stakeholders' engagement (number/year) | Quantitative | <ul style="list-style-type: none"> • Interviews • Conduct survey • Behavioral mapping, participatory mapping | Sources: - Author - ASLA, 2018 |
| | Increased recreational & social values | Visitors' engagement in social & recreational activities - number or percent of total | Quantitative | <ul style="list-style-type: none"> • Space Syntax, Placemaker, Participatory photomapping PPM, Systematic • Use direct observation, following the Gehl Institute's Public Life Tools, SOPARC, or other observational methods. • Conduct a survey of users to determine the quantity, quality, or frequency of their use of the site for recreational or social activities. • Observation of Play & Recreation in Communities | Sources: - LAF, 2018 - ASLA, 2018 - Author |
| | Added social & connectivity values | Enhanced social networks, increased feeling of belonging and perception of safety - Quality of the visitor experience and people with special needs | Quantitative | <ul style="list-style-type: none"> • Interviews, surveys, behavioral observation / mapping • Conduct a survey of site users or of residents or visitors to determine if the space is perceived as safe or whether the design intervention changed their perceptions about safety • Conduct a survey of site users or of those from a population of interest, such as people with disabilities or those experiencing homelessness, to determine the nature and quality of their experience. Questions should focus on issues of access and inclusion | Sources: - Author - Song & et. al, 2020 - LAF, 2018 |

5.4.7 Socio-Cultural; Aesthetic Values Aspects

Table (20) Adopted Social indicators for measuring wetland Aesthetic value impact, Source: Author from references

| | | | | | |
|-------------------------------|---------------------------|---|--------------|---|--|
| Socio-Cultural Impact Factors | Visual Aesthetic Value | Scenic quality and increased aesthetic / visual acceptance | Quantitative | <ul style="list-style-type: none"> • Interviews • Surveys • Use of regional, local or customized indices to assess scenic quality using before- after scoring scheme or compare to similar sited without interventions | Sources: - LAF, 2018 - ASLA, 2018 - Author |
| | Odor Reduction Efficiency | Enhanced odor in the site - Quality of air odor and reduction in bad smells | Quantitative | <ul style="list-style-type: none"> • Conduct a survey of site users and those who live or spend time in the vicinity to determine the degree of improvement of the odor in the site after • Conduct a survey of users to determine the degree of improvement of the Park in the community | Sources: - Author - Duarte, A., et. al., 2010 - Zakaria, Y. et al., 2021 - Aide, M. et al., 2020 |

5.4.8 Economical -Technical; Economic Values Aspects

*Table (21) Adopted Economic indicators for measuring wetland Economic value impact,
Source: Author from references*

| | | | | | | |
|--------------------------------------|-----------------|---------------------------------|--|--------------|--|--|
| Economical -Technical Impact Factors | Economic Values | Catalyzing Economic Development | Increase in investment due to project | Quantitative | Public records of increased investments after project implementation | Sources: - LAF, 2018 - ASLA, 2018 - Author |
| | | Land Use Value | Added value to project site and adjacent properties | Quantitative | Public records of increased sales and rental values of site and nearby properties after intervention | Sources: - LAF, 2018 - ASLA, 2018 - Author - Fitzgerald, S., 2018 |
| | | Economic Savings | Economic efficiency during construction & operation phases | Quantitative | - Public records of comparable costs - Life Cycle Cost Analysis LCCA | Sources: - Author - ASLA, 2018 - Hunter, R., et al., 2018 - Balkema, A. et al., 2002 |
| | | Potentials of Economic Revenue | Economic revenue from project | Quantitative | Economic revenue generated through tickets, produced plantations | Sources: - Author - ASLA, 2018 - Balkema, A. et al., 2002 |

5.4.9 Economical -Technical; Technical Values Aspects

*Table (22) Adopted Technical indicators for measuring wetland Technical value impact,
Source: Author from references*

| | | | | | | |
|--------------------------------------|------------------|---|--|--------------|--|--|
| Economical -Technical Impact Factors | Technical Values | Construction process Flexibility | Flexible construction process by using new technologies or ideas - Opportunities for cost reduction in earthwork costs | Quantitative | - Records for construction process - Adaptation to various opportunities of new technologies in the construction process - Estimate the cost savings using local cost estimates for excavation, grading, imported fill, and/or off-site disposal | Sources: - Author - Zakaria, Y. et al., 2021 - Balkema, A. et al., 2002 |
| | | Operation and maintenance process flexibility | Adaptation to different opportunities in the maintenance and the operation process | Quantitative | - Records for operation and maintenance process - Adaptation to various opportunities of new technologies in the construction process - Estimate the cost savings using new technology ideas for operation and maintenance | Sources: - Author - Zakaria, Y. et al., 2021 - Muga H., et. al., 2008 - Balkema, A. et al., 2002 |
| | | Future potential for upgrading | Opportunities for upgrading - Project upgrading through expansion or project improvement and new technology | Quantitative | - Studies and plans for future expansion of the projects - Studies for project's improvements and better-quality achievements in different impacts and water quality - Studies of upgrading to new technology | Sources: Author |

5.5 Tools for Indicators Measurements

Table (23) Adopted environmental indicators for measuring wetland impact and sustainability, Source: Author

| Category | Indicator | Sub-Indicators /Description | Type | Tools for Method Measurement |
|-----------------------|---------------------------------|--|--------------|--|
| Environmental Aspects | Climatic Aspects | Air Quality - Air quality: Improvement in air quality due to increased vegetation cover | Quantitative | i-Tree Eco (v 6) i-Tree Streets (v 5.1) Air Quality Index (AQI) |
| | | Urban Micro-Climate - Heat Island Effect: % of decrease in Heat Island Effect due to increased vegetation cover and water bodies | Quantitative | i-Tree Eco (v 6) ENVI-met <u>Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) v 3.3.3</u> The Natural Capital Project 2016 |
| | | Carbon Footprint - Carbon Footprint: amount of carbon dioxide and other GHG emissions associated with the wetland project compared to conventional treatment plant | Quantitative | i-Tree Eco (v 6) <u>Pathfinder: Landscape Carbon Calculator</u> Climate Positive Design 2019 National Tree Benefits Calculator (treebenefits.com) Carbon Footprint Calculator STELLA v. 9.1, |
| | Sustainability | Energy - Construction Energy Conservation: % of energy conserved during construction stage compared to conventional treatment plant - Operation Energy conservation: % of operational electrical energy conserved compared to conventional treatment operations measured over a specific temporal scale | Quantitative | i-Tree Eco (v 6) Power Consumption Calculator |
| | | Materials - Recycled Materials: % of materials that is recycled or acquired from onsite materials - Hazardous Materials: % of hazardous materials and chemicals employed in water treatment process compared to conventional treatment processes | Quantitative | <u>Recycled Content (ReCon) Tool</u> U.S. Environmental Protection Agency 2010 <u>Recycling and Reusing Landscape Waste Cost Calculator</u> U.S. Environmental Protection Agency 2008 |
| | | Solid/Liquid Wastes - Quality/ Quantity of wastes: % of waste materials discharged during the treatment process | Quantitative | <u>Waste Reduction Model (WARM) v14</u> U.S. Environmental Protection Agency 2016 |
| | | Soil - Quality/ Quantity of soil creation, preservation & restoration: % of fertile or restored soils | Quantitative | ASLA, Landscape Arch. Technical Information Series: A Landscape Performance + Metrics Primer for Landscape Architects – Soils and Amendments |
| | Biodiversity; Habitat Diversity | Flora (Vegetation) - Number of Flora species introduced into the habitat | Quantitative | i-Tree Eco (v 6) <u>Universal Floristic Quality Assessment Calculator</u> <u>National Tree Benefits Calculator</u> (treebenefits.com) Openlands 2015 |
| | | Fauna - Number of Fauna species introduced into the habitat | Quantitative | <u>iNaturalist</u> California Academy of Sciences and National Geographic Society 2017 <u>eBird</u> Cornell Lab of Ornithology 2009 |
| | Water | Water Reused - Water Reused: % of water reused or reintroduced to the irrigation system. | Quantitative | <u>Resource Conserving Landscaping Cost Calculator</u> U.S. Environmental Protection Agency 2007 |
| | | Water Quality - Water quality: % of pathogens removed through the constructed wetland | Quantitative | <u>Long-Term Hydrologic Impact Analysis</u> Local Government Environmental Assistance Network 2011 |

5.6 Conclusion

This CWP Assessment matrix enables reviewers to methodically understand the total sustainability performance of the CW Park and the sustainability performance during both construction and operation phase. The assessment is simplified through different quantitative matrices and easy to understand visual charts for better evaluation and assessment of the chances for improvements and to identify weakness and strength impacts on environment. This helps in the management of existing CW Parks and for the planning and designing attempts for new CW Parks projects. The suggested assessment matrices and charts are believed to be a powerful assessment tool, which makes the proposed CWP Assessment Index user-friendly and easy to understand for different levels of practitioners and works as a summary of the project's impact assessment reports.

Chapter 6: Case Study, 10th of Ramadan Wetland Park

Introduction

This chapter provides a review of expected environmental assessment and performance of a constructed wetland park in arid climate city in Egypt, as well as a comprehensive analysis using the proposed CWP Index to achieve a clear understanding of the expected sustainability achievement of CWP and its benefits in arid climate cities.

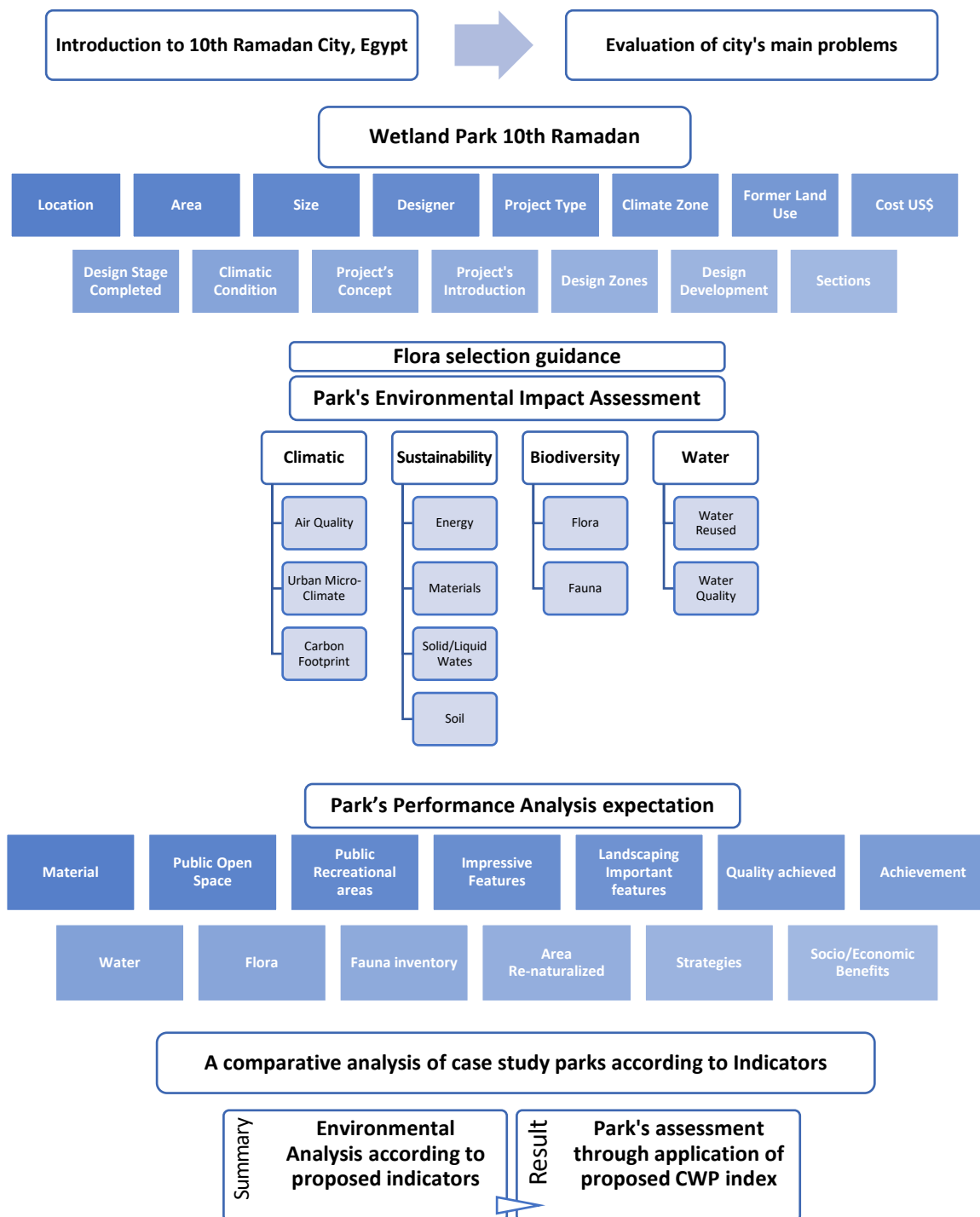


Fig. (149) Chapter 6, Methodology and structure, Source: Author

Introduction to 10th of Ramadan City

10th of Ramadan city, established in 1977, is located on the peripheries of the city of Cairo and is considered part of Greater Cairo District and is one of the cities built near Greater Cairo to increase the inhabited area and alleviate the social and economic difficulties affecting the city as a result of overcrowding and urbanization. Along the Cairo-Ismailia desert route, the city is in the eastern Nile delta area. It is bordered on the west by the Cairo-Belbies desert road, on the east by the El Shabab canal, on the north by the Ismailia canal, and on the south by the Cairo-Ismailia desert road. The city has a present size of 465 km² and a population of 650 000 people, which is predicted to grow to 2 500 000 by 2030. (Hegazy, I., et al., 2017). It is a new, first-generation urban community and one of the most industrialized cities. The city has many industrial zones which covers many industries. Some of which include food processing, plastics, garments, paper, electronics, building materials, textiles, steel, furniture, and pharmaceuticals.

The city lacks sufficient green spaces and scarcity of both Flora and Fauna species. Both domestic and industrial sewer water for the city is accumulated and disposed of in three oxidation basins since 1980. The surplus from these ponds is drained through constructed and natural channels in Wadi Al-Watan about 15 km northeast of the city and collected in the swamps to threaten Al Shabab channel for fresh water. This wastewater accumulated in the swamps is used directly to irrigate the new, replanted areas. (Al-Nimr, A., et al., 2015)

The city is underpopulated and is suffering from repellent from people and workers to reside in. Despite its proximity to the city of Cairo, it suffers from serious problems in attracting residents. The city poses several problems (transportation, housing, cost of living, etc.). Another important reason is its desertic urban and pollution from industrial areas. Nevertheless, scarcity of social facilities and services. The city contains a huge desert area designated for buildings which are abundant and other empty residential settlements.

1. The Most polluting industries
2. Vegetation low water, high pollution tolerance, drought tolerant, evergreen, solar tolerant
3. Water scarcity

Table (24) 10th Ramadan Evaluation Matrix according to the African Green City Index,

Source: Hegazy, I., et al., 2017 and edited by Author

| | Well below Average | Below Average | Average | Above Average | Well above Average | Comment | Average |
|--------------------------|--------------------|---------------|---------|---------------|--------------------|---|---------------------------------------|
| Energy and CO2 | | • | | | | Access to Electricity: 96.6% Electricity Consumption per Capita: 7.5 CO2 emissions (Kg/person): 340.5 Clean Energy Policy: 4 | 84.2 6.4 983.9 0-10 |
| Land Use | | | • | | | Population Density (Person/km ²): 1400 Population living in informal settlements: 1% Green spaces per capita (m ² /person): 27.6 Land use police: 6 | 4578.1 38 73.6 0-10 |
| Transport | | • | | | | Public transport network (km/lm ²): 1.9 Urban mass transport policy: 4 Congestion reduction policy: 4 | 2.7 0-10 0-10 |
| Waste | | | • | | | Waste generated (kg/person/year): 370 Waste collection and disposal policy: 5 Waste recycling and reuse policy: 5 | 407.8 0-10 0-10 |
| Water | | | • | | | Access to potable water: 98.9% Water consumption (Litter/person/day): 210 Water system leakage: 20% Water quality policy: 5 Water sustainability policy: 5 | 91.2 187.2 30.5 0-10 0-10 |
| Sanitation | | | • | | | Population with access to improved sanitation: 92.9% Sanitation policy: 5 | 48.1 0-10 |
| Air Quality | | • | | | | Clean Air Quality: 4 | 0-10 |
| Environmental governance | | • | | | | Environmental Management: 4 Environmental monitoring: 3 Public participation: 3 | 0-10 0-10 0-10 |
| Overall Result | | ● | | | | | |

From the previous table the following arguments could be concluded: (Hegazy, I., et al., 2017)

Clean energy policies require development and that per capita power consumption is high. There is a fair land use policy, but urban sprawl is a problem. There are no substantial modern public transit networks in the city. However, policy may be improved, for example, by embracing more efforts to reduce traffic congestion. It should be emphasized that most residents rely on private transportation, such as private minibuses and taxis. Another problem is the lack of continuity in public transportation planning. There are no attempts to reduce traffic congestion, such as carpool lanes, no-car days, or toll roads.

In the 10th of Ramadan, waste generation was estimated to be 370 kg per person per year; however, it is unclear how much waste created in industrial areas is included in these estimates. Waste policies, as well as the entire waste management plan, are less frequent. With 290 liters per person per day, the city consumes more water than the index average. The average leakage rate is substantial, reaching 20% in the tenth month of Ramadan. There are no strict water policies in force. Furthermore, there are no water efficiency programs in place, including grey water recycling or public conservation awareness. The city lacks a code that governs cleanliness and infrastructure. When it comes to executing sanitation rules and programs, the city has several challenges. Unfavorably, access to sanitation, like access to potable water, does not usually entail residential connections to the sewage system. On a policy level, the city is being hindered and is falling behind. In terms of enforcement, the city does not conduct regular supervision of on-site treatment programs in households or common spaces, and existing rules are either not enforced or are only monitored seldom.

Local governments appear to pay little attention to air quality. There is a scarcity of thorough and comparative data on this subject that may be used. According to reports, even with legislation in place, Egyptian towns confront significant challenges in reducing pollution, which frequently exceeds hazardous levels. Egypt's environmental policy is mostly decided at the national or regional level, instead of at the local level. This means that environmental issues receive less consideration in general compared if they were seen at a local level.

The Egyptian cities have been regarded as being largely independent in terms of environmental management at the urban scale. Despite the existence of environmental policies, executive regulation of these programs is often restricted. The city's efforts to publish environmental performance statistics on a regular basis, as well as to complete broad-based baseline environmental studies, are limited or non-existent. Environmental challenges should be handled holistically by the city.

6.1. Introduction:

Location: 10th Ramadan City, Egypt, 2020-2021

Climate Zone: Arid Hot-Climature

Scale: Large-scale Park; 35 km²



Fig. (150) 10th of Ramadan Site Location, Source: Google Map, Date accessed: Sep. 1, 2021

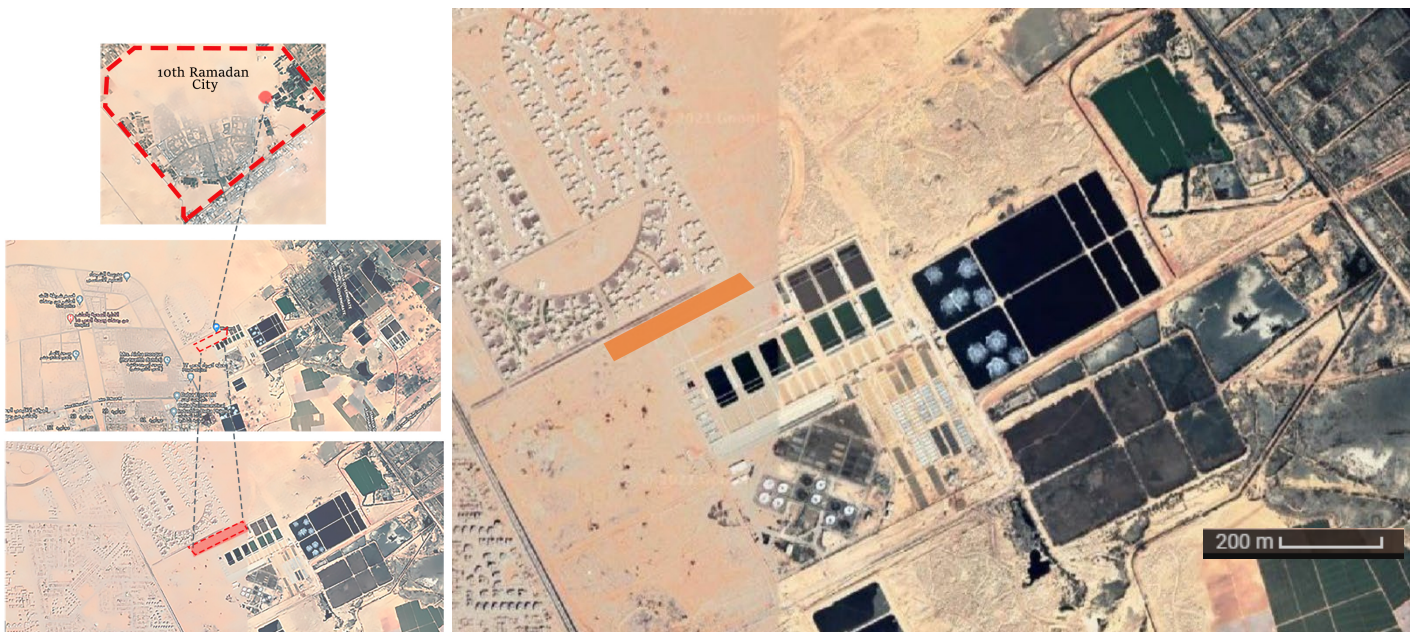


Fig. (151) 10th of Ramadan Wetland Park's Location, Source: Google Map edited by Author, Date accessed: Sep. 1, 2021

6.2. Analysis:

6.2.1. Introduction

| | | |
|---|---|--|
| Case Study | 10 th of Ramadan Constructed Wetland Park | |
| Location | 10th of Ramadan City, Egypt | |
| Area | 35 Km2 Width 35m * Length 1.056 km, 30°20'17.9"N 31°47'19.2"E | |
| Designer & Project Partners | Landscape Architecture Design Team: Arch Space Group Project Host: Cairo Higher Institute for Engineering Computer Science and Management, Project Partners: NWRC, National Water Research Center in Egypt, New Urban Communities Authority | |
| Project Type | Park/Open space Wetland creation/restoration / Waterfront redevelopment | |
| Climate Zone | Arid Climate, BwH Hardiness Zone: 10 | |
| Former Land Use | <p>Brownfield</p> <p>The site was an abundant long desertic ribbon originally planned by the municipality as sewage station's green belt in front of the residential buildings, areas around the sewage with radius of 2- 5 kms are currently brownfields and are planned to be potential upgrading of the park after the end of the 2 phases.</p> <p><i>Fig. (152) Site Land-use, Source: Google Earth, Edited by Author, Date accessed: 26 Feb. 2022</i></p> | |
| Cost US\$ Completed | Budget: 2.6 million Egyptian pounds (165 thousand USD), Fund Organization: Science & Technology Development Fund, 2020 – 2022 | |
| Challenges & Climate Condition | 10th of Ramadan city has many industrial zones which covers many industries, some of which are most polluting industries. The city has a hot-arid desert climate with dry summers and mild winters with little precipitation. As a result of water scarcity and the use of municipal water for irrigation, the cost of irrigation is high and consequently, the city lacks sufficient green spaces and scarcity of both Flora and Fauna species. | |
| Project's Concept | Environmental and sustainable Approach. An ecological sustainable Design through natural processes, Low-Maintenance Urban Park for municipal wastewater treatment. | |
| Introduction | <p>The Park area has a long rectangular strip shape with area of approximately 36km² (35m width and 1.056 km long). The project land is in the designated green belt area in front of the sewage treatment plant, which separates the wastewater area from the residential complex "Al-Andalus". The proposed location can be described as a desert land with no vegetation adjacent to the sewage treatment plant. On the opposite side is a residential settlement which is until now unoccupied, due to the desertic area around and the scarcity of social services. The location does not require much preparation activities as the land is relatively flat and no existing buildings or structures. Remnants of excavation work for the waterway will be used in the construction of the hill and the different levels inside the garden.</p> <p><i>Fig. (153) Park's Site Map, Source: Google Earth, Edited by Author, Date accessed: 26 Feb. 2022</i></p> | |

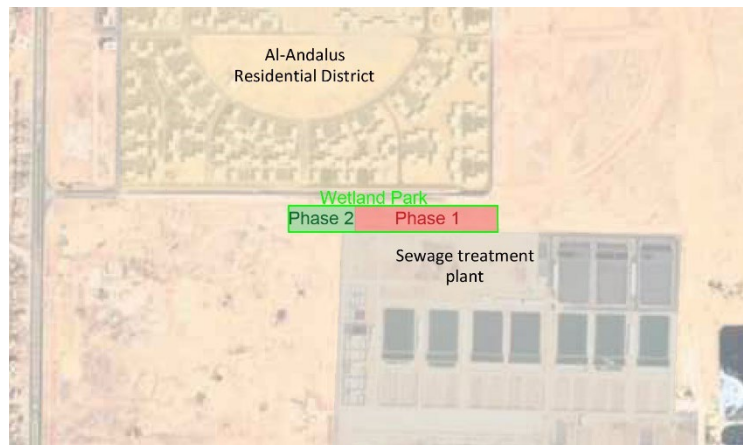
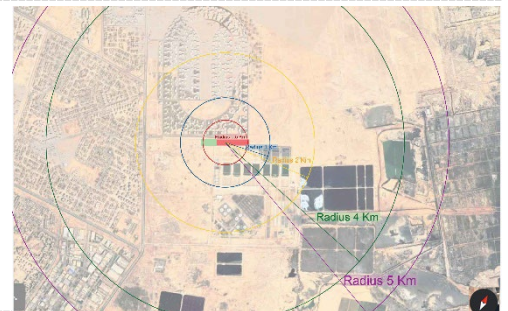


Fig. (153) Park's Site Map, Source: Google Earth, Edited by Author, Date accessed: 26 Feb. 2022

6.2.2. Design Zones

Fig. (154) Design Zones, Source: Designers Academic team, edited by Author

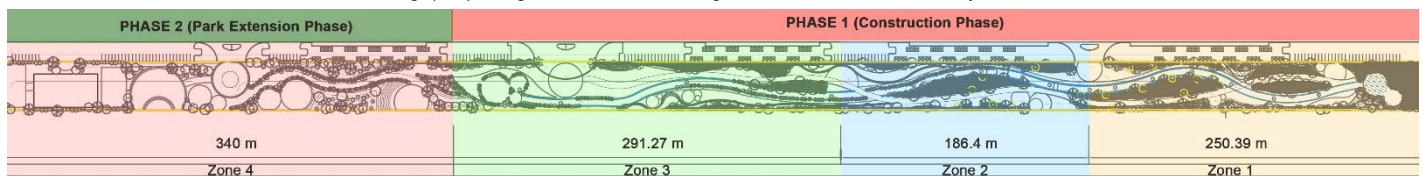
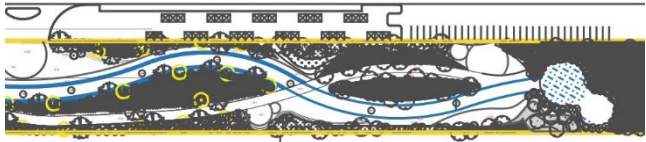

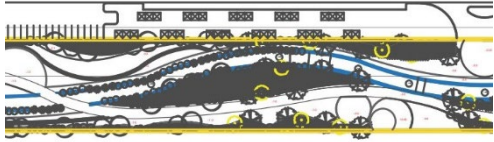

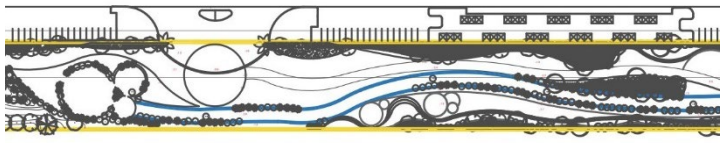

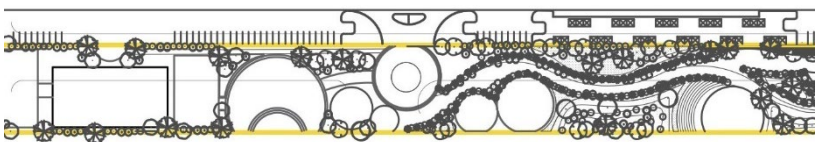



Table (25) Zone characteristics and Theme purposes, Source: Author, Figures by Designers Academic team

| | | | |
|--------|-----------------------|---|---|
| Zone 1 | Water Pathway: | Sub-Surface Wetland (1m depth, 0.75 m gravel, water pass under gravel) |   |
| | Vegetation: | Cactii and Aromatic Vegetation Aquatic at Water Pathway | |
| | Theme Purpose: | Barrier: Prevent users from contact with water at earlier stage of treatment Aroma: Aromatic Plantings to treat any bad odours and Mosquito Repellant Water: Low - Minimum Water Requirement | |
| Zone 2 | Water Pathway: | Sub-Surface Wetland (1m depth, 0.75 m gravel, water pass under gravel) Free-Surface Wetland (1m depth, 0.25 m gravel and 0.5 m water above) |   |
| | Vegetation: | Shading and Barrier Aquatic at Water Pathway | |
| | Theme Purpose: | Buffer: Eliminate accessibility to zone 1 through buffer vegetation area Shade: Offer shading for users Water: Minimum Water Requirement | |
| Zone 3 | Water Pathway: | Free-Surface Wetland (1m depth, 0.25 m gravel and 0.5 m water above) |   |
| | Vegetation: | Ornamental and Aromatic Aquatic at Water Pathway | |
| | Theme Purpose: | Bloom: Long blooming period Ornament: Attractive Ornamental features Suitable for public recreational spaces Water: Moderate Water Requirement | |
| Zone 4 | Water Pathway: | Pond & Fountain |   |
| | Vegetation: | Biodiversity Aesthetic and Shading | |
| | Theme Purpose: | Biodiversity: Attractive to different Fauna Species Public Use: Vegetations are user-safe Water: Moderate Water Requirement | |

6.2.3. Design Development

The design proposal was focusing on the development of Low-Cost Techniques due to the low budget. Excavation of the water path is reused as backfilling for the proposed hill in zone 1, which is mainly designed to create an aesthetic barrier to the adjacent sewage treatment system and to eliminate the access to the infill pond due to the quality of the water at the earlier stage, where it is designed to prevent the direct contact of visitors with the water. Reclaimed soil is used to create a few meters-high hill, offering aesthetic green space of cactus and various types of spiny plants that provides scenic views in addition to its role as a barrier that prevent users from direct contact with water at earlier stage of treatment. The vegetation species includes aromatic plantings to reduce any bad odors and species that are known as mosquito repellent. Most of the species planted on the hill have low to minimum water requirement. Zone 2 was designed as a buffer zone before zone 1 which offer diverse activities for recreational opportunities, such as walking, hiking and jogging without offering resting areas. Zone 3 includes opportunities for family and group gatherings and areas for resting and picnicking, with diverse designed family compartments, and semi-enclosed areas that respect users' cultural and offer privacy. At the entrance area in zone 3 a nice fountain with nature decorated bridges for a natural scenic view between water and greens as a lookout point to enjoy beautiful scenery and nice picture frame for visitors to grab a nice memory with nature. The design for Zone 4 was focusing on offering spaces for various community activities and as a potential for future upgrading of the park.

For community engagement and for targeting the community needs, two workshops were held for stakeholders and people with interest and another for students and professionals of architecture, urban and landscape, where their contribution was requested for offering ideas and design development for zone 4 to achieve the best design proposal that fulfill the needs of the community.

3D Model represented to stakeholders in a workshop on 6, 7 February 2021,

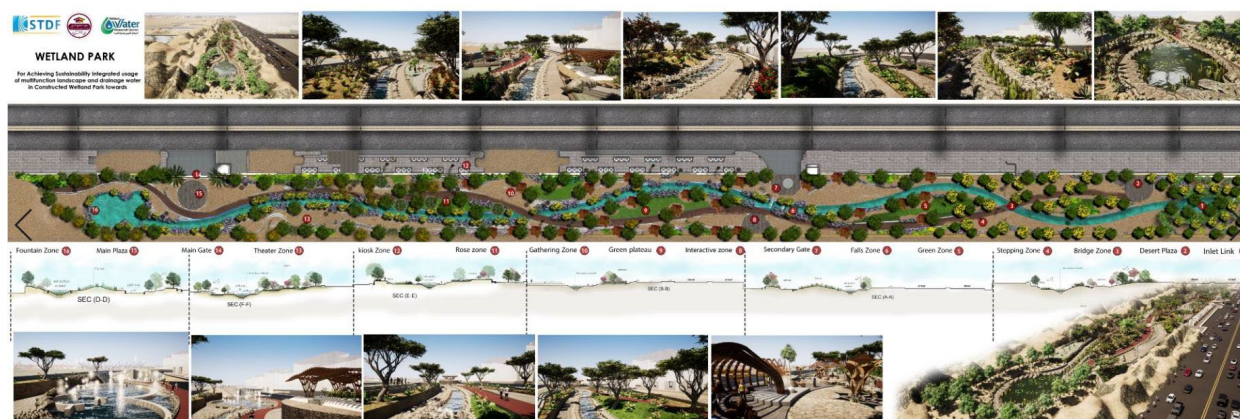


Fig. (155): 3D Model for 10th Ramadan Wetland Park, Source: Designers Academic team

Project's Phases

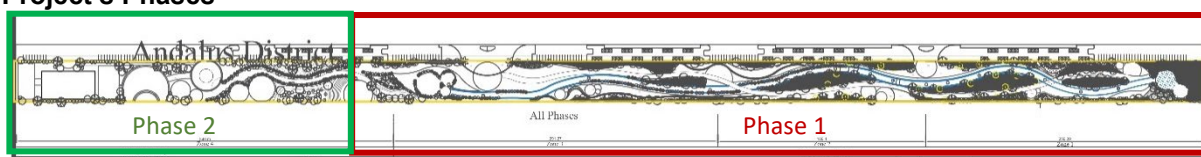


Fig. (156): Phases of the Wetland Park Project, Source: Designers Academic team, edited by Author

The project was mainly initiated as an academic project, which is primary focusing on academic research and theoretical outputs of studies of research papers, master's thesis and doctoral work. The group of researchers applied for a fund to put all these studies as a practical prototype of constructed wetland parks in Egypt. They managed to get a fund from the STDF, Science and Technology Development Fund, in Egypt with the amount of 2 million Egyptian pounds, equivalent to almost 165 thousand US dollars, for both the academic and practical construction of the park and for a time duration of two years for execution.

Due to the available low budget for the project, the project timeline was distributed to 2 phases, the first phase is the construction phase and includes the first 3 zones of the park which comprises the constructed wetland water path, while phase 2 is the Park extension phase and is represented in zone 4, which mainly accommodate the various recreational, commercial and economic activities. This phase could be further developed after the end of the funding timeline required by the funding authorities.

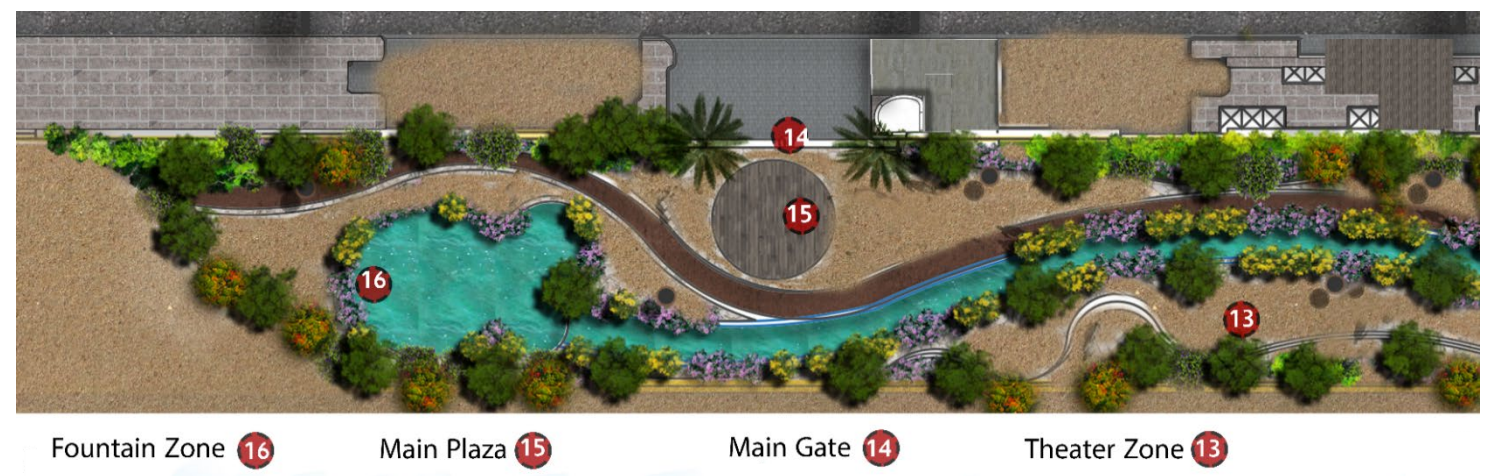
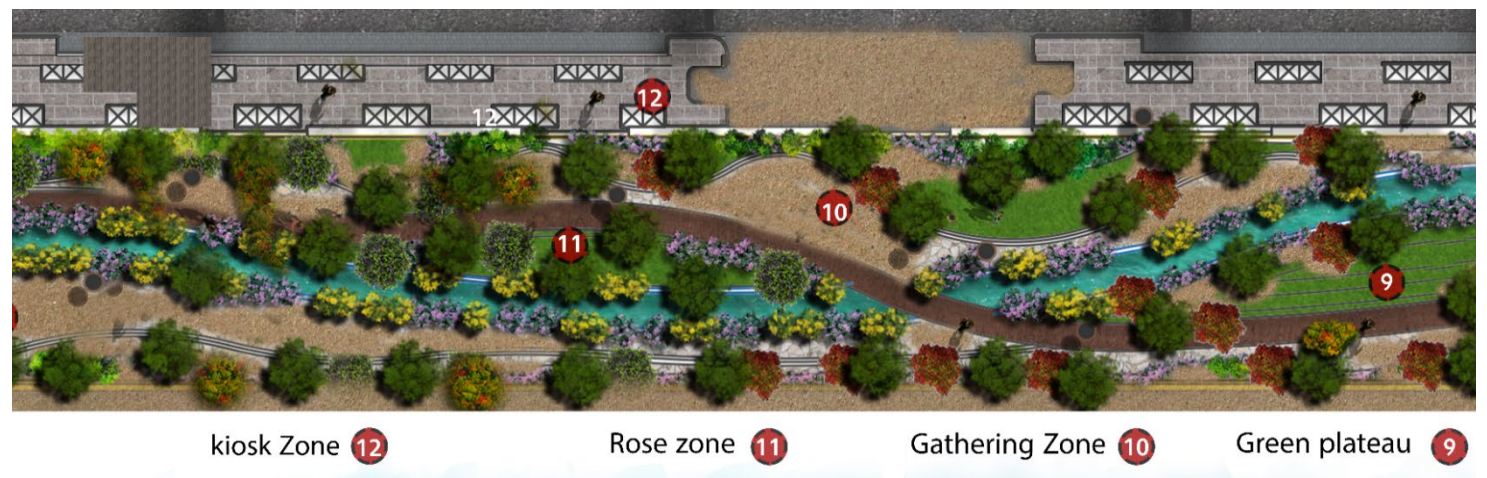
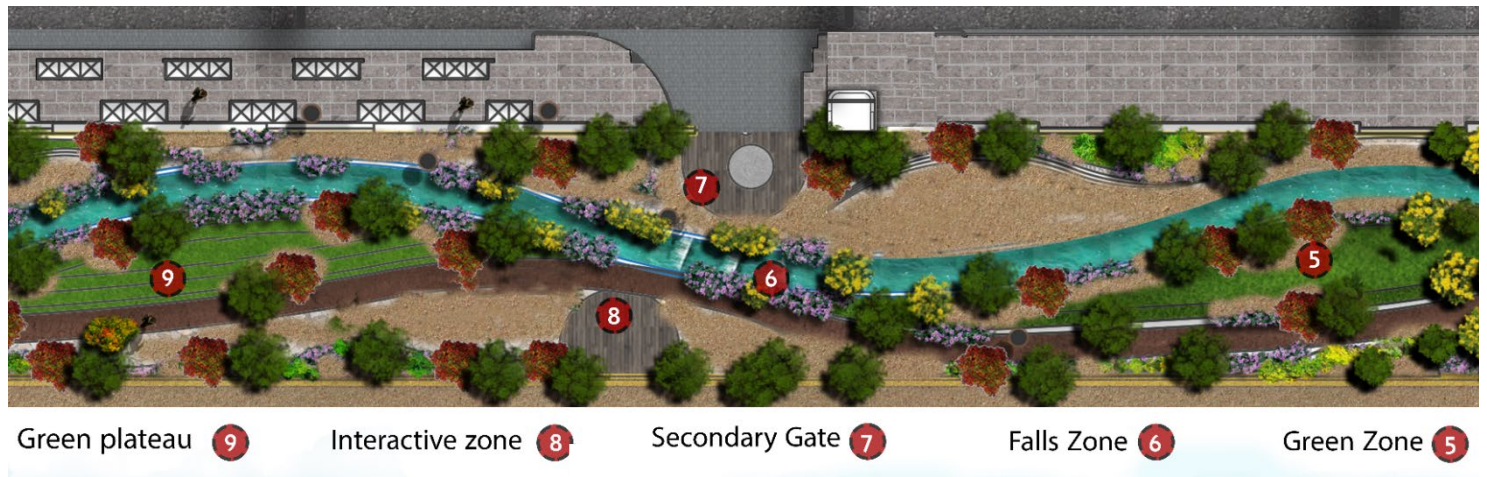
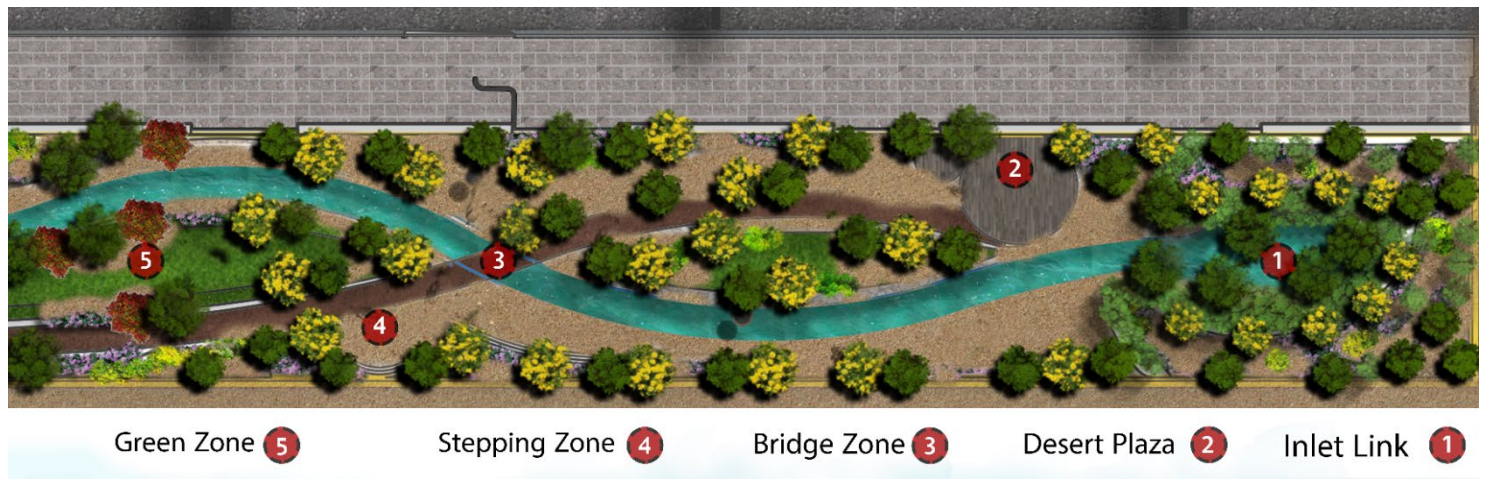


Fig. (157): Wetland Park Plan, Source: Designers Academic team

6.2.4. Sections

The design of the park included various levels that offer diverse opportunities for different activities and dynamic user experience of the park. The pedestrian paths are routing shaded pathways to enhance the visitors' interactions with diverse wetland plants and wildlife with descriptive signage of species and ecological process of the park. The paths bring the visitors closer allowing access to inner spaces of living landscape for an educational natural experience while providing numerous recreational opportunities for vibrant experience while engaging with the water. The park also encompasses multiple choices of exploration network paths for various age group visitors that fulfill their diverse needs of activities through different path materials. The twisting pathways along the wetland creates a series of thresholds and visual aesthetic interest for a dynamic experience that offers opportunities for recreation, education, and research for the various visitors' group age needs. The created platforms and nodes on the pedestrian network create various types of gathering areas.

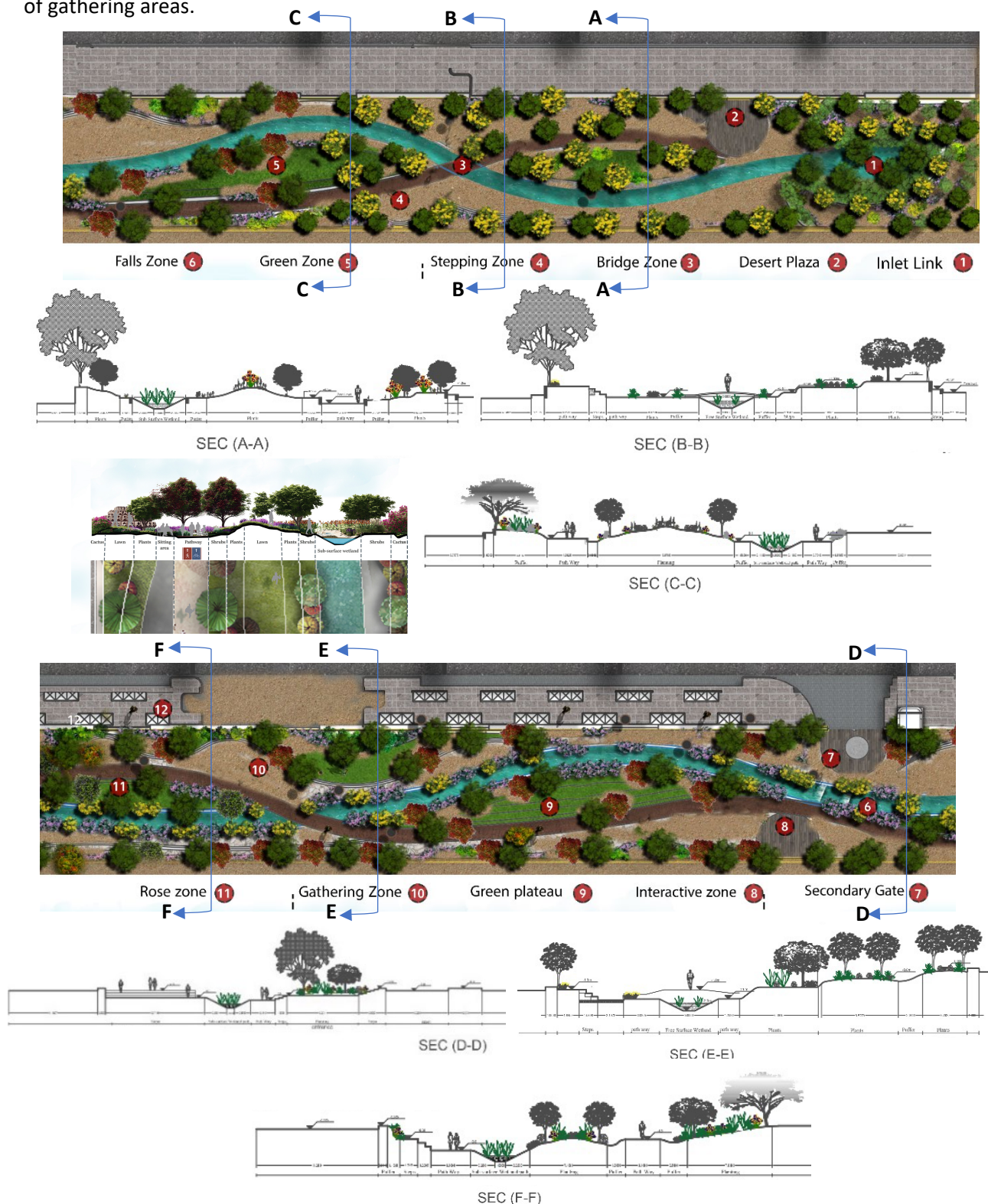


Fig. (158): Sections of the Wetland Park, Source: Designers Academic team, edited by Author

6.3. Flora selection guidance

For a sustainable design of the park, the study included analysis of native species in Egypt as a guidance for the selection process in the landscape design of the park. The selection process mainly included native species to improve the ecological benefits and achieve sustainability. The native species in Egypt was determined according to the Royal Botanic Gardens, Kew, Plants of the World Online. *See appendix (3) for detailed Native species.*

1. Plants Selection process

The process depended on selecting the most adequate vegetation that are adaptive to the Park's climate in the city of the 10th of Ramadan. The selection criteria included the major points that affects the sustainability and the environmental performance of the park and other aesthetic values; this includes:

- Blooming Seasons
- Colorfulness to create various themes for the different zones in the park
- Impacts on Micro-Climate improvement; *Co2 & Nitrogen Reduction / Evaporative Effect/ Amount of Shade (Heat Island Effect) / Water Consumption*
- Sun Requirements to be adapted with the arid climate in the Park's Location
- Salinity, Drought and Wind tolerance
- Maintenance requirements
- Plant's Life Cycle
- Water Requirements
- Design Use and Value
- Aesthetic Values and Aromatic features
- Attractiveness to different species to help increase the biodiversity and develop Fauna in the Park

The Selection of plants focuses on using different Species that creates diversity of Flora. The consecutive blooming seasons ensures that the Park have a dynamic impression of changing themes according to the Season and according to the function in each Zone.

2. Selected species analysis

The following tables shows the specifications and recommendation of use according to the climate's adaptation for the following species categories:

- Palms
- Trees
- Shrubs
- Climbers
- Groundcovers
- Succulents and Cacti
- Ornamental Grasses

All tables Analysis are done by Author, sources of information: ElMasry, L., 2014; RBG Kew, 2021; Gardenia, 2021; BdS, 2021; Bruns, 2019; Gardeners' World, 2021; NC Extension, 2021; CABI, 2021; Minnesota Wildflowers, 2021

6.3.2.1 Palms and Trees

Table (26) Selected Palm and Tree species specs and recommendation of use, Source: Author

| No | Latin Name | Name in Arabic | شهور التبرعم Bloom | | | | | | | | | | | | Form (Shape and Seasonal Changes) تكوين النبات (الشكل والتغيرات الموسمية) | رائحة Aroma | Growth Rate معدل النمو | Water إحتياج للمياه | شمس Sun | Salinity تحمل الملوحة | Drought تحمل الجفاف | Wind تحمل الرياح | Living Years | Selection |
|----|-------------------------------------|--|--------------------|---|---|---|---|---|---|---|---|----|----|----|--|-----------------------|---------------------------|------------------------|----------|-----------------------------|------------------------|---------------------|----------------------------------|-----------------|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | | | | | | | | | | |
| 1 | PALMS | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Hyphaene thebaica (L.) Mart. | نخيل الدوم | | | | | 5 | 6 | | | | | | | Evergreen | No Aroma | Slow | Low | Full Sun | M. Tolerance 600-800 ppm | H. Tolerance | High | Long living plant, 100-120 years | Check |
| 2 | Phoenix dactylifera L. | نخيل البلخ | | | | 4 | | | | | | | | | Evergreen | No Aroma | Fast | Moderate | Full Sun | Tolerant 800-1200 ppm | Tolerant | High | Long living plant, 80-100 years | Recommended |
| 2 | TREES | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Acacia nilotica | أكاسيا نيلوتيكيا، الشوط، شوكة مصرية، القرض | | | | | 5 | 6 | | | | | | | Evergreen | No Aroma | Slow | Low | Full Sun | Tolerant 800-1200 ppm | H. Tolerance | High | Long living plant, 80-100 years | Recommended |
| 2 | Albizia lebbeck (L.) Benth. | البج، دكن الباشا | | | | 4 | 5 | 6 | | | | | | | Deciduous | Flower | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi | Long living plant, 90-100 years | Recommended |
| 3 | Balanites aegyptiaca (L.) Delile | هبلنج، بلخ السكر، بلخ الصحراء | | | | 3 | 4 | | | | | | | | Semi Deciduous | No Aroma | Slow | Low | Full Sun | Tolerant 800-1200 ppm | H. Tolerance | High | Long living plant, 50-60 years | Not Recommended |
| 4 | Bauhinia variegata | خف الجبل | | | 2 | 3 | 4 | | | | | | | | Deciduous | No Aroma | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Intolerant | Semi | Long living plant, 40-50 years | Recommended |
| 5 | Cassia nodosa | كاسيا لنوزاء المشرق | | | | | | | 6 | 7 | 8 | 9 | 10 | | Deciduous | Flower | Fast | Moderate | Full Sun | L. Tolerance 300-600 ppm | Tolerant | Semi | Long living plant, 40-50 years | H. Recommended |
| 6 | Citrus medica | نارج، أترج | | | | 3 | 4 | | | | | | | | Evergreen | Flower / Leaf / Fruit | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi | Medium living plant, 25-30 years | Not Recommended |
| 7 | Citrus sinensis | برتقال | | | | 2 | 3 | 4 | | | | | | | Evergreen | Flower / Leaf / Fruit | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi | Medium living plant, 15-20 years | Not Recommended |
| 8 | Cordia myxa L. | شجرة المبيض | | | | | | | 6 | 7 | | | | | Deciduous | Leaf | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Long living plant, 40-50 years | H. Recommended |
| 9 | Delonix regia (Bojer ex Hook.) Raf. | بولسبان | | | | 4 | 5 | 6 | 7 | 8 | | | | | Deciduous | No Aroma | Fast | Moderate | Full Sun | Tolerant 800-1200 ppm | Tolerant | Semi | Long living plant, 50-60 years | H. Recommended |
| 10 | Erythrina crista-galli L. | شجرة العرجان | | | | 4 | 5 | 6 | 7 | 8 | 9 | | | | Deciduous | No Aroma | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi | Medium living plant, 20-25 years | H. Recommended |
| 11 | Erythrina caffra | إزربينا كافرا | | | | 4 | 5 | | | | | | | | Deciduous | No Aroma | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | H. Tolerance | High | Long living plant, 45-50 years | Recommended |
| 12 | Ficus sycomorus L. | الجوز | | | | | | | | 7 | 8 | | | | Evergreen | No Aroma | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Long living plant, 150-160 years | H. Recommended |
| 13 | Haematoxylum campechianum L. | هيماتوكس، هيدا | | | | | | | 6 | 7 | | | | | Evergreen | Flower | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Long living plant, 90-100 years | Not Recommended |
| 14 | Moringa peregrina (Forssk.) Fiori | حب البسار، الحبة الغالية | | | | 4 | 5 | | | | | | | | Deciduous / Semi Deciduous | Flower | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi | Long living plant, 80-90 years | Not Recommended |
| 15 | Olea europaea L. | الزيتون | | | | | | | 6 | 7 | | | | | Evergreen | Flower / Fruit | Slow | Low / Moderate | Full Sun | Tolerant 800-1200 ppm | H. Tolerance | High | Long living plant, 100-120 years | Not Recommended |
| 16 | Pongamia pinnata (L.) Pierre | بونجاميا | | | | | | | 5 | 6 | | | | | Deciduous | Flower | Moderate | Moderate | Full Sun | Intolerant | Tolerant | Semi | Long living plant, 50-70 years | Check |
| 17 | populus alba | الحور | | | | | | | 5 | 6 | | | | | Deciduous | No Aroma | V. Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Long living plant, 90-100 years | Not Recommended |
| 18 | prosopis juliflora | بروسوبس، الغاف | | | | | | | 6 | 7 | | | | | Evergreen | No Aroma | Fast | Low | Full Sun | Tolerant 800-1200 ppm | H. Tolerance | High | Long living plant, 90-100 years | Recommended |
| 19 | Ricinus communis L. | الخروع | | | | | | | 4 | 5 | | | | | Evergreen | No Aroma | Fast | Moderate | Full Sun | Tolerant 800-1200 ppm | Tolerant | Semi | Long living plant, 40-50 years | Not Recommended |
| 20 | salix babylonica | صفصاف أم شعور، الصفصاف الباك | | | | | | | 3 | 4 | | | | | Deciduous | No Aroma | Moderate | Moderate | Full Sun | Intolerant | Tolerant | Semi | Long living plant, 90-100 years | H. Recommended |
| 21 | Sesbania sesban Syn. S. argyptiaca | السبان، البان | | | | | | | 5 | 6 | 7 | | | | Deciduous | No Aroma | Fast | Low | Full Sun | Tolerant 800-1200 ppm | Tolerant | Semi | Short living plant 5-10 years | Recommended |
| 22 | Tamarindus indica L. | تمر هندي | | | | | | | 6 | 7 | | | | | Deciduous | Flower | Slow | Moderate | Full Sun | Intolerant | Tolerant | Semi | Long living plant, 80-100 years | Not Recommended |
| 23 | Tamarix aphylla (L.) H.Karst. | الطرقة | | | | | | | | | 7 | 8 | | | Evergreen | No Aroma | Moderate | Low | Full Sun | Tolerant 800-1200 ppm | Tolerant | High | Long living plant, 110-120 years | Recommended |
| 24 | Ziziphus spina-christi (L.) Desf. | الحبق، السدر | | | | | | | 5 | 6 | | | | | Evergreen | Flower | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Long living plant, 80-90 years | Recommended |

6.3.2.2 Shrubs

Table (27) Selected Shrub species specs and recommendation of use, Source: Author

| No | Latin Name | Name in Arabic | شهور الإزهار Bloom | | | | | | | | | | | | Form (Shape and Seasonal Changes) تكوين النبات (الشكل و التغيرات الموسمية) | رائحة Aroma | Growth Rate معدل النمو | Water إحتياج للمياه | شمس Sun | Salinity تحمل الملوحة | Drought تحمل الجفاف | Wind تحمل الرياح | Living Years | Selection | |
|----|---|-----------------------------------|--------------------|---|---|---|---|---|---|---|---|----|----|----------------------------|---|----------------|---------------------------|--------------------------|--------------------------|--------------------------|--------------------------|----------------------------------|-----------------------------------|--------------------------------|----------------|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | | | | | | | | | | | |
| 3 | SHRUBS | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Abutilon species | أبو تيلون | | | | 4 | 5 | 6 | 7 | 8 | | | | | Evergreen | No Aroma | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | H. Tolerance | Semi | Medium living plant, 30-40 years | H. Recommended | |
| 2 | Ageratum houstonianum Mill. | أجرتم | | | | 4 | 5 | 6 | 7 | | | | | Evergreen | No Aroma | Fast | Moderate | Partial Shade / Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Short living plant, 8-10 years | Not Recommended | | |
| 3 | Atriplex halimus L. | أترليكس | | | | | 5 | 6 | | | | | | Evergreen | No Aroma | Fast | Moderate | Full Sun | H. Tolerance >1500 ppm | H. Tolerance | High | Medium living plant, 15-20 years | Not Recommended | | |
| 4 | Barleria cristata | بارليريا | | | | | 5 | 6 | 7 | 8 | | | | Evergreen | No Aroma | Moderate | Moderate | Full Sun | L. Tolerance 300-600 ppm | Tolerant | Semi | Medium living plant, 10-15 years | Recommended | | |
| 5 | Caesalpinia pulcherrima (L.) Sw. | سيزالينيا | | | | | 5 | 6 | 7 | 8 | | | | Deciduous | No Aroma | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | H. Tolerance | Semi | Medium living plant, 20-25 years | Recommended | | |
| 6 | Carissa grandiflora | كاريسا جرانديفلورا | | | | | 5 | 6 | 7 | 8 | | | | Evergreen | Flower | Moderate | Low | Full Sun | M. Tolerance 600-800 ppm | H. Tolerance | High | Medium living plant, 30-40 years | Check | | |
| 7 | Cassia alata Syn. Senna alata | كاسيا ألاتا | | | | | 5 | 6 | 7 | | | | | Deciduous | No Aroma | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | H. Tolerance | Semi | Medium living plant, 15-20 years | Not Recommended | | |
| 8 | Cassia didymobotrya Syn. Senna | سنا صفراء | | | | | 5 | 6 | 7 | 8 | | | | Evergreen | Flower / Leaf | Fast | Moderate | Full Sun | Tolerant 800-1200 ppm | Tolerant | High | Long living plant, 50-60 years | Recommended | | |
| 9 | Cestrum ayraniticum Syn. C. chaculanum | مسك الليل | | | | | | | 6 | 7 | 8 | | | Semi Deciduous / Evergreen | Flower | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi | Medium living plant, 25-30 years | H. Recommended | | |
| 10 | Cestrum elegans | ملكة الليل | | | | | | | 6 | 7 | 8 | | | Evergreen | Flower | Fast | Moderate | Full Sun | Intolerant | L. Tolerance | Semi | Medium living plant, 10-15 years | Recommended | | |
| 11 | Clerodendrum inerme | باسمين زلف | | | | | | | 6 | 7 | 8 | | | Evergreen | Flower / Leaf | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Long living plant, 50-60 years | Recommended | | |
| 12 | Dichrostachys cinerea (L.) Wight & Arn. | ديكروستاشيس | 1 | 2 | | | | | | | | 9 | 10 | 11 | 12 | Semi Deciduous | No Aroma | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Long Living plant, 40-50 years | H. Recommended |
| 13 | Euphorbia continifolia | ايكويريا حمراء، بنت الفضل الحمراء | 1 | | | | | | | | | | | 12 | Deciduous | No Aroma | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi | Medium living plant, 25-30 years | Recommended | |
| 14 | Euphorbia pulcherrima | بنت الفضل | 1 | | | | | | | | | | | 12 | Deciduous | No Aroma | Fast | Moderate | Full Sun | Intolerant | Tolerant | Semi | Medium living plant, 30-50 years | H. Recommended | |
| 15 | Ficus carica L. | التين البرشومي | | | | | 5 | 6 | 7 | 8 | | | | | Deciduous | No Aroma | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi | Long living plant, 20-25 years | Not Recommended | |
| 16 | Gladiolus species | جلادولوس | 1 | 2 | 3 | | | | | | | | | | Evergreen | No Aroma | Fast | Moderate | Full Sun | Intolerant | Intolerant | Non Resistant | Short living plant, only one year | Check | |
| 17 | Hibiscus sabdariffa L. | كرنبه | | | | | | 6 | 7 | | | | | | Evergreen | Flower / Fruit | Moderate | Moderate | Full Sun | L. Tolerance 300-600 ppm | L. Tolerance | High | Medium living plant, 7-10 years | Check | |
| 18 | Hibiscus rosa-sinensis | هيبسكس أحمر | | | | | 5 | 6 | 7 | 8 | | | | | Evergreen | No Aroma | Fast | Moderate | Full Sun | L. Tolerance 300-600 ppm | Tolerant | Semi | Medium living plant, 7-10 years | H. Recommended | |
| 19 | Hibiscus syriacus | هيبسكس سرياقوس، هيبسكس أبيض | | | | | | 6 | 7 | 8 | | | | | Deciduous | No Aroma | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Short living plant, 4-7 years | Not Recommended | |
| 20 | Jasminum sambac | الفل | | | | | 4 | 5 | 6 | 7 | 8 | 9 | | | Evergreen | Flower | Slow | Moderate | Full Sun | Intolerant | Intolerant | Semi | Short living plant, 7-10 years | H. Recommended | |
| 21 | Justicia adhatoda Syn. Adhatoda vasica | يوستاشيا بيشاء | | | | | 5 | 6 | 7 | | | | | | Evergreen | No Aroma | Fast | Moderate | Full Sun | Tolerant 800-1200 ppm | Tolerant | High | Medium living plant, 10-12 years | Not Recommended | |
| 22 | Justicia spicigera | يوستاشيا يرتقال | | | | | 5 | 6 | 7 | | | | | | Evergreen | Leaf | Fast | Moderate | Full Sun | Tolerant 800-1200 ppm | M. Tolerance | High | Medium living plant, 10-12 years | Not Recommended | |
| 23 | Lantana camara | لانطانا كامارا | | | | | 5 | 6 | 7 | 8 | | | | | Evergreen | Flower / Leaf | Fast | Moderate | Full Sun | Tolerant 800-1200 ppm | M. Tolerance | High | Medium living plant, 20-25 years | Recommended | |
| 24 | Lanvandula angustifolia Syn. L. officinalis | لافندر | | | | | | | | 7 | 8 | 9 | | | Evergreen | Flower / Leaf | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi | Short living plant, 2-3 years | Recommended | |
| 25 | Lawsonia inermis L. | حنه يلدی | | | | | | 6 | 7 | 8 | | | | | Evergreen | Flower | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Medium living plant, 30-40 years | H. Recommended | |
| 26 | Ocimum basilicum | ريحان | | | | | | 6 | 7 | 8 | | | | | Evergreen | Flower / Leaf | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | M. Tolerance | Semi | Short living plant, 1-2 years | Check | |
| 27 | Pentas lanceolata Syn. P. carnea | پنتاس | | | | | 5 | 6 | 7 | 8 | | | | | Evergreen | No Aroma | Fast | Moderate | Partial Shade / Full Sun | Tolerant 800-1200 ppm | M. Tolerance | Semi | Short living plant, 3-5 years | H. Recommended | |
| 28 | Salvia rosmarinus Spenn. | روز ماري، حضا لسان | | | | | 5 | 6 | | | | | | | Evergreen | Flower / Leaf | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Short living plant, 4-7 years | Check | |
| 29 | Vitex agnus-castus L. | فيتيكس أغنوس | | | | | | 6 | 7 | 8 | | | | | Evergreen | Flower | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Medium living plant, 20-30 years | H. Recommended | |

6.3.2.3 Climbers and Groundcovers

Table (28) Selected Climber and Groundcover species specs and recommendation of use, Source: Author

| No | Latin Name | Name in Arabic | Bloom (الزهور) | | | | | | | | | | | | Form (Shape and Seasonal Changes) تكوين النبات (الشكل والتغيرات الموسمية) | Aroma رائحة | Growth Rate معدل النمو | Water إحتياج للمياه | Sun شمس | Salinity تحمل الملوحة | Drought تحمل الجفاف | Wind تحمل الرياح | Living Years | Selection | |
|----|---|-------------------------------|----------------|---|---|---|---|---|---|---|---|----|----|----|--|---------------|------------------------|---------------------|--------------------------|--------------------------|---------------------|------------------|----------------------------------|-----------------|--|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | | | | | | | | | | | |
| 4 | Climbers | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Bougainvillea Stans | جهنمية الفريش | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Evergreen | No Aroma | Fast | Moderate | Full Sun | Tolerant 800-1200 ppm | Tolerant | High | Medium living plant, 25-28 years | H. Recommended | |
| 2 | Clerodendrum splendens | كلودرا، طربوش الملك | 1 | 2 | | | | | 6 | 7 | 8 | | | 12 | Evergreen | No Aroma | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | M. Tolerance | Semi | Medium living plant, 20-25 years | H. Recommended | |
| 3 | Clerodendrum thomsoniae | كرمة القلب الدامي | | 2 | 3 | 4 | | | | | | | | | Evergreen | No Aroma | Moderate | Moderate | Full Sun | Intolerant | M. Tolerance | Semi | Medium living plant, 12-15 years | Recommended | |
| 4 | Ipomoea pes-caprae (L.) R.Br. | ايبوميا خلف الجميل | | | | | | | 7 | 8 | 9 | | | | Deciduous | No Aroma | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Medium living plant, 12-15 years | Recommended | |
| 5 | Jasminum grandiflorum subsp. floribundum (R.Br. ex Fresen.) P.S.Green | ياسمين بلدي | | | | | | | 6 | 7 | 8 | 9 | | | Deciduous | Flower | Fast | Moderate | Full Sun | L. Tolerance 300-600 ppm | Tolerant | Semi | Medium living plant, 12-15 years | H. Recommended | |
| 6 | Solanum seaforthianum Andrews | سولانم، سيفورسيانم | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | | Evergreen | No Aroma | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi | Medium living plant, 12-15 years | H. Recommended | |
| 7 | Stephanotis floribunda | ستيفانوتيس | | | | | | | 7 | 8 | 9 | 10 | 11 | 12 | Evergreen | Flower | Moderate | Moderate | Full Sun | L. Tolerance 300-600 ppm | M. Tolerance | Semi | Medium living plant, 12-15 years | H. Recommended | |
| 5 | Groundcovers | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Achillea millefoliumm | أشيليا، ألف زهرة | | | 2 | 3 | 4 | 5 | | | | | | | Evergreen | No Aroma | Fast | Moderate | Partial Shade / Full Sun | Tolerant 800-1200 ppm | Intolerant | Semi | Short living plant, 3-5 years | H. Recommended | |
| 2 | Alternanthera species | الترنانثيرا حمراء أو خضراء | | | | | | | 6 | 7 | | | | | Evergreen | No Aroma | Fast | Moderate | Full Sun | Intolerant | Intolerant | High | Short living plant, 5-7 years | Recommended | |
| 3 | Anemone species | أنيمون | | | | | 2 | 3 | 4 | | | | | | Evergreen | No Aroma | Fast | Moderate | Partial Shade / Full Sun | Intolerant | Intolerant | Non Resistant | Short living plant, 5-7 years | Recommended | |
| 4 | Lantana camara nana | لانطانا صفراء | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Evergreen | Flower / Leaf | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | L. Tolerance | High | Medium living plant, 10-15 years | H. Recommended | |
| 5 | Lantana montevidensis | لانطانا زرقاء | | | | | | | 5 | 6 | 7 | 8 | | | Semi Deciduous | Flower / Leaf | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi | Short living plant, 5-7 years | Recommended | |
| 6 | Matthiola incana | مثنور | | 2 | 3 | 4 | | | | | | | | | Evergreen | Flower | Fast | Moderate | Full Sun | Intolerant | Intolerant | High | Short living plant, 1-2 years | Not Recommended | |
| 7 | Mentha spicata L. | نعناع | | | | | | | | 7 | 8 | | | | Evergreen | Flower / Leaf | Fast | Moderate | Partial Shade / Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Short living plant, 3-5 years | Recommended | |
| 8 | Narcissus species | الترنجس | | | 2 | 3 | 4 | 5 | 6 | | | | | | Evergreen | Flower | Fast | Moderate | Partial Shade / Full Sun | Intolerant | Intolerant | Semi | Short living plant, 7-10 years | Not Recommended | |
| 9 | Origanum vulgare Syn. Origanum majorana | بردقوش | | | | | | | | | 8 | 9 | | | Evergreen | Flower / Leaf | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Short living plant, 3-5 years | Recommended | |
| 10 | Pelargonium peltatum | جارونيا، كرو، مدادة | | | 2 | 3 | 4 | 5 | 6 | | | 9 | 10 | 11 | Evergreen | Flower / Leaf | Fast | Moderate | Partial Shade | M. Tolerance 600-800 ppm | Intolerant | Semi | Short living plant, 2-3 years | H. Recommended | |
| 11 | Portulaca grandiflora | رجلة صبار الزهور | | | | | | | | 6 | 7 | 8 | 9 | | Evergreen | No Aroma | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Intolerant | High | Short living plant, 3-5 years | H. Recommended | |
| 12 | Santolina chamaecyparissus Syn. S. incana | شيخ خرساني | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Evergreen | Flower / Leaf | Fast | Low | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Short living plant, 8-10 years | Not Recommended | |
| 12 | Tagetes erecta | الطفيضة | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Evergreen | Flower / Leaf | Fast | Moderate | Partial Shade / Full Sun | Tolerant 800-1200 ppm | Tolerant | High | Short living plant, 1-2 years | H. Recommended | |
| 14 | Thymus vulgaris | زعتار جبلي | | | | | | | | 7 | 8 | | | | Evergreen | Flower / Leaf | Slow | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Short living plant, 5-7 years | Recommended | |
| 16 | Verbena hybrida | فربيينا بلدي، فربيينا إنجليزى | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Evergreen | No Aroma | Fast | Moderate | Full Sun | Intolerant | Tolerant | Semi | Short living plant, 1-2 years | H. Recommended | |

6.3.2.4 Succulents & Cacti and Ornamental Grasses

Table (29) Selected Succulents / Cacti and Ornamental Grass species specs and recommendation of use, Source: Author

| No | Latin Name | Name in Arabic | Bloom (الزهور) | | | | | | | | | | | | Form (Shape and Seasonal Changes) تكوين النبات (الشكل (والانغيمات الموسمية | Aroma رائحة | Growth Rate معدل النمو | Water إحتياج للمياه | Sun شمس | Salinity تحمل الملوحة | Drought تحمل الجفاف | Wind تحمل الرياح | Living Years | Selection |
|----|---|----------------------|----------------|---|---|---|---|---|---|---|---|----|----|----|---|-------------|------------------------|---------------------|--------------------------|--------------------------|---------------------|------------------|----------------------------------|-----------------|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | | | | | | | | | | |
| 6 | Succulents & Cacti | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Adenium obesum Syn. A. arabicum | جواقة زهور | | | | | | | | | | | | | Deciduous | Flower | Slow | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi | Short living plant, 8-10 years | H. Recommended |
| 2 | Mesembryanthemum cordifolia Syn. Aptenia, Litocarpus | أبتنيا | | | | | | | | | | | | | Evergreen | No Aroma | Fast | Moderate | Partial Shade / Full Sun | Tolerant 800-1200 ppm | Tolerant | High | Short living plant, 2-3 years | H. Recommended |
| 3 | Calotropis procera (Aiton) W.T.Aiton | العشار، العشر | | | | | | | | | | | | | Evergreen | Flower | Moderate | Low | Full Sun | Tolerant 800-1200 ppm | H. Tolerance | Semi | Medium living plant, 15-20 years | Check |
| 4 | Crassula hottentot | كراسولا السبخة | | | | | | | | | | | | | Evergreen | No Aroma | Slow | Low | Full Sun | L. Tolerance 300-600 ppm | Tolerant | High | Short living plant, 2-3 years | Recommended |
| 5 | Euphorbia lactea | شمعدان | | | | | | | | | | | | | Evergreen | No Aroma | Fast | Low | Full Sun | Tolerant 800-1200 ppm | H. Tolerance | High | Medium living plant, 30-40 years | Not Recommended |
| 6 | Euphorbia milii var. splendens | شوكة المسحج | | | | | | | | | | | | | Evergreen | No Aroma | Slow | Low | Partial Shade / Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Short living plant, 5-9 years | H. Recommended |
| 7 | Opuntia ficus-indica Syn. O. engelmanni | التين الشوكي | | | | | | | | | | | | | Evergreen | No Aroma | Moderate | Minimum | Full Sun | Tolerant 800-1200 ppm | H. Tolerance | High | Long living plant, 40-50 years | Not Recommended |
| 8 | Opuntia phaeacantha | تين شوكي أحمر | | | | | | | | | | | | | Evergreen | No Aroma | Moderate | Minimum | Full Sun | M. Tolerance 600-800 ppm | H. Tolerance | High | Long living plant, 40-50 years | Not Recommended |
| 9 | Sedum acre | سديم | | | | | | | | | | | | | Evergreen | No Aroma | Slow | Low | Partial Shade / Full Sun | Intolerant | Tolerant | High | Medium living plant, 25-30 years | H. Recommended |
| 10 | Yucca filamentosa | يوكا إبرية | | | | | | | | | | | | | Evergreen | No Aroma | Slow | Low | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Medium living plant, 25-30 years | H. Recommended |
| 7 | Ornamental Grasses | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Cortaderia selloana (Schult. & Schult.f.) Asch. & Graebn. | حشيشة كورتديريا | | | | | | | | | | | | | Evergreen | No Aroma | Fast | Moderate | Full Sun | Tolerant 800-1200 ppm | H. Tolerance | High | Medium living plant, 12-15 years | H. Recommended |
| 2 | Cymbopogon citratus (DC.) Stapf | حشيشة الليمون | | | | | | | | | | | | | Evergreen | Leaf | Fast | Moderate | Partial Shade / Full Sun | M. Tolerance 600-800 ppm | L. Tolerance | High | Short living plant, 7-9 years | Check |
| 3 | Miscanthus sinensis Andersson | حشيشة الميكائنيس | | | | | | | | | | | | | Evergreen | No Aroma | Slow | Low | Partial Shade / Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | Short living plant, 7-9 years | Recommended |
| 4 | Paspalum vaginatum Sw. | باسالم صبي شور، نجيل | | | | | | | | | | | | | Evergreen | No Aroma | Fast | Moderate | Full Sun | Tolerant 800-1200 ppm | Intolerant | High | Short living plant, 5-7 years | H. Recommended |

3. Vegetation According to Zone's Theme

Zone 1

| | | |
|--------|----------------|---|
| Zone 1 | Water Pathway: | Sub-Surface Wetland (1m depth, 0.75 m gravel, water pass under gravel) |
| | Vegetation: | Cactii and Aromatic Vegetation Aquatic at Water Pathway |
| | Theme Purpose: | Barrier: Prevent users from contact with water at earlier stage of treatment Aroma: Aromatic Plantings to treat any bad odours and Mosquito Repellant Water: Low - Minimum Water Requirement |

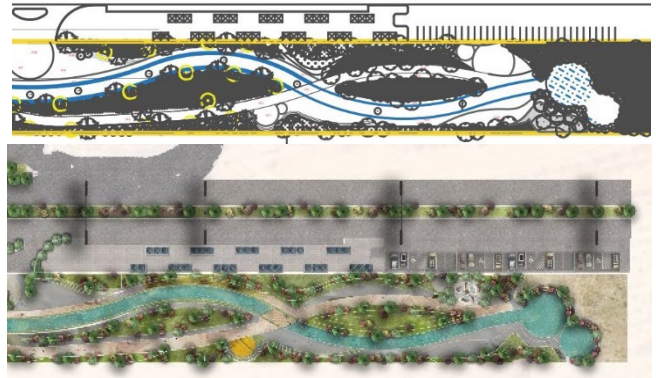


Table (30) Selected species for zone 1, Source: Author

| Latin Name | Name in Arabic | Design Use and Value مجالات استخدام النبات في التصميم | ملاحظات ايجابية أو سلبية | | Selection | Reason of Selection |
|---|---|--|---|--|------------------|--|
| | | | Positive | Negative | | |
| PALMS | | | | | | |
| Hyphaene thebaica (L.) Mart. | نخيل الدوم | Along river banks to stabilize soil and control erosion Leaves provide raw materials used in basketry in upper Egypt Fruits are used for food, beverage and medicinal applications | Tolerates temperate climate Considered sacred by ancient Egyptians | Very difficult to transplant | Check | Stabilize soil and control erosion |
| Phoenix dactylifera L. | نخيل البلح | An ornamental shade and street palm when planted at close intervals Planted mainly for its edible fruits, timber and fronds | An ornamental shade a Long living plant, 80-100 years Easily transplanted | Requires extra water for better fruit production Risk of people eating fruit | Recommend | Ornamental Plant Offers shading for users |
| TREES | | | | | | |
| Acacia nilotica | أكاسيا نيلوتিকা، شوكة السنط، مصرية، القرض | Popular desert landscape plant in parks and garden A hedge, a shade tree or used along rivers and water channels A source of wood, fuel and medicine | A hedge, a shade tree or used along rivers and water channels Long living plant, 80-100 years | | Recommend | Shade along Water channel |
| SHRUBS | | | | | | |
| Cestrum ayraniticum Syn. C. chaculanum | مسك الليل | A specimen or used in clusters with strongly scented flowers Used in shrub borders in parks and gardens; requires pruning | Strongly -scented flowers Attracts butterflies Eradicating mosquito, (potential botanical insecticide agents for the control of lepidopteron, beetles and mosquito larvae.) Popular in Egypt Medium living plant, 25-30 years | Requires pruning, High Maintenance | High Recommended | Aromatic flower Mosquito Repellent |
| Cestrum elegans | ملكة الليل | An ornamental plant used in shelters border, against sunny wall, around entrances and courtyards Grown for its fragrant, funnel shaped flowers | Aromatic flower Mosquito Repellent | Low tolerance | Recommend | Aromatic flower Mosquito Repellent |
| Climbers | | | | | | |
| Bougainvillea Stans | جهنمية أفرنجی | Climbing or Shrubby-shaped flowering plant, which covers arches, pergolas and fences Can serve as hedge if properly trimmed | Blooming all year Attractive colors | Requires trimming Frost-intolerant Hard to transplant after it is 1.5 m long | High Recommended | Everblooming Colorful hedge and barrier border |
| Groundcovers | | | | | | |
| Thymus vulgaris | زعر جلی | Ideal low groundcover, used in edges, borders and rock gardens Seaside friendly that is frost-hardy and attraxts bees Medicinal and culinary uses | In Egypt exists and has broad fleshy leaves Attracts bees, Biodiversity Easily transplanted | | Recommend | Moderate Water Requirements Effective security barriers |
| Succulents & Cacti | | | | | | |
| Adenium obesum Syn. A. arabicum | جوافة زهور | Very attractive as a bonsai Along coastal promenades; in desert and rock garden Containers in courts, roofs, balconies and terraces | Aromatic Flower Very attractive as a bonsai; red, pink or rarely white flowers Frost-tolerat Easily transplanted | Poisonous milky sap | High Recommended | Moderate Water Requirements Effective security barriers |
| Mesembryanthemu m cordifolia Syn. Aptenia, Litocarpus | أبتنیا | Desert and rock gardens, excellent as creeping groundcover Slope tolerant, erosion control plant A great hanging basket plant | Blooming 4 months Protect from exessive Winter moisture Slope tolerant, erosion control plant Low Maintenance Easily transplanted | | High Recommended | Moderate Water Requirements Effective security barriers |
| Calotropis procera (Aiton) W.T.Aiton | العشار، الغشتر | Important role in improving soil fertility and soil water holding capacity Flowers are used in making floral tassels; root skin, latex, flowers, leaves and fruits are used in medicine | Blooming 4 months Aromatic Flower; large, fragrant beautiful white Low water requirements Easily transplanted | Bitter in taste with toxic symptoms Very harmful to the eyes | Check | Low Water Requirements Effective security barriers |
| Crassula hottentot | كراسولا السبحة | Desert and rock gardens Could be planted in pots Attractive leaves | Unique Form, and attractive leaves Low water requirements Easily transplanted | Unpleasant Flower odor Excessive water damages undersoil plant stems | Recommend | Low Water Requirements Effective security barriers |
| Euphorbia milii var. splendens | شوكة المسيح | Desert and rock gardens Roof and terrace gardens in full light Containers; in mixed beds and hedges | Blooming all year Attractive red flower Low water requirements Easily transplanted | Parts of the plant are poisonous Causes skin irritation | High Recommended | Low Water Requirements Effective security barriers |
| Opuntia ficus-indica Syn. O. engelmanni | التين الشوكی | Desert gardens and in borders with other cacti Culinary and medicinal uses Effective security barriers Edible ovoid, spiny yellow-orange fruits, up to 10 cm long, famous in Egypt | Minimum Water Requirements Effective security barriers, could be used at Zone 1 Easily transplanted | Bristles cause intense irritation to skin | Check | Minimum Water Requirements Effective security barriers |
| Opuntia phaeacantha | تین شوكی أحمر | Desert gardens and in borders with other cacti Culinary and medicinal uses Effective security barriers Edible spherical, spineless red or purple fruits, 2-4 cm long, famous in Egypt | Minimum Water Requirements Effective security barriers, could be used at Zone 1 Easily transplanted | | Check | Minimum Water Requirements Effective security barriers |
| Sedum acre | سیدم | Desert and rock gardens Roof gardens and green-walls in green architecture to conserve energy | Divide every 3-4 years Attractive matt-forming foliage form Flowers as many tiny star-shaped, yellow green Low water requirements Easily transplanted | Cut back to maintaine shape | High Recommended | Low Water Requirements Effective security barriers |
| Yucca filamentosa | یوكا ابرية | Excellent in rock gardens and as an accent among other perennials Mixed borders and natural areas Medicinal plant Low maintenance xeriscape | Very showy inflorescence on erect spike; up to 3.7 m high With many individual white flowers; 5 cm long Low water requirements Easily transplanted | The plant dies after flowering and providing new plants Flowers may require hand pollination to set seeds | High Recommended | Low Water Requirements Effective security barriers |
| Ornamental Grasses | | | | | | |
| Cymbopogon citratus (DC.) Stapf | حشيشة الليمون | Used for beds and borders Does well in tubs and containers Commonly used in teas, soups, curries and medicinal uses | Aromatic Leaf Easily transplanted Could be used at Zone 1 where people are not required to stav | Not used near walkways or play areas (sharp edges) Short living plant, 7-9 years | Check | Aromatic flower Effective security barriers |

Zone 2

| | |
|-----------------------|---|
| Water Pathway: | Sub-Surface Wetland (1m depth, 0.75 m gravel, water pass under gravel) Free-Surface Wetland (1m depth, 0.25 m gravel and 0.5 m water above) |
| Vegetation: | Shading and Barrier Aquatic at Water Pathway |
| Theme | Buffer: Eliminate accessibility to zone 1 through buffer vegetation area |
| Purpose: | Shade: Offer shading for users Water: Minimum Water Requirement |

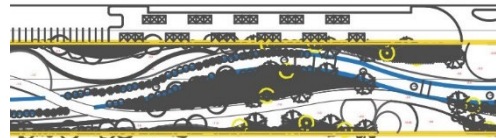


Table (31) Selected species for zone 2, Source: Author

| Latin Name | Name in Arabic | Design Use and Value مجالات استخدام النبات في التصميم | ملاحظات ايجابية أو سلبية Comments | | Selection | Reason of Selection |
|---|---|--|--|--|------------------|--|
| | | | Positive | Negative | | |
| PALMS | | | | | | |
| Hyphaene thebaica (L.) Mart. | نخيل الدوم | Along riverbanks to stabilize soil and control erosion Leaves provide raw materials used in basketry in upper Egypt Fruits are used for food, beverage and medicinal applications | Tolerates temperate climate Considered sacred by ancient Egyptians | Very difficult to transplant | Check | Stabilize soil and control erosion |
| Phoenix dactylifera L. | نخيل البلح | An ornamental shade and street palm when planted at close intervals Planted mainly for its edible fruits, timber and fronds | An ornamental shade a Long living plant, 80-100 years Easily transplanted | Requires extra water for better fruit production Risk of people eating fruit | Recommend | Ornamental Plant Offers shading for users |
| TREES | | | | | | |
| Acacia nilotica | أكاسيا نيلوتيكيا، السنط، شوكة القرض، مصرية، القرض | Popular desert landscape plant in parks and garden A hedge, a shade tree or used along rivers and water channels A source of wood, fuel, and medicine | A hedge, a shade tree or used along rivers and water channels Long living plant, 80-100 years | | Recommend | Shade along Water channel |
| Albizia lebbeck (L.) Benth. | البیخ، دقن الباشا | Shade tree in parks, streets, and parking lots A timber tree. Popular in furniture and medicinal industry | Shade tree Long living plant, 90-100 years | | Recommend | Offers shading for users Moderate Water Requirement |
| Cordia myxa L. | شجرة المخيط | A shade ornamental tree with highly decorative flowers The wood holds much historical value in Egypt, as it was used by the Ancient Egyptians in creating mummy casting | Shading with highly decorative flowers Historical value in Egypt? Aromatic leaves Long Living plant, 40-50 years | | H. Recommended | Offers shading for users Moderate Water Requirement |
| Erythrina caffra | إرثرینا كفرا | Ideal plant in gardens and parks for its unique appearance Popular tree for its long flowering period and easy cultivation | Ideal in parks for its unique appearance Long flowering period and easy cultivation Long living plant, 45-50 years High Tolerance to drought | | Recommend | Long flowering period Unique ornamental appearance |
| salix babylonica | صفصاف أم الشعور، الصفصاف البابی | Specimen weeping tree adds a dramatic effect near lakes and bodies of water Used as a shade tree in villages and large parks | Dramatic effect near lakes and bodies of water Used as a shade tree Long living plant, 90-100 years | | H. Recommended | Offers shading for users Moderate Water Requirement |
| Sesbania sesban Syn. S. argyptiacia | المسبان، البان | A shade tree used in fencing Improvement of soil fertility and in reclamation of saline soil In Africa it is used to feed animals, people and to obtain wood | Low water requirements A shade tree Improvement of soil fertility and in reclamation of saline soil | Short living plant 5-10 years, Medium Maintenance Risk of people eating fruit | Recommend | Offers shading for users Low Water Requirement |
| Tamarix aphylla (L.) H.Karst. | الطرفة | A windbreak or hedge for agricultural fields A shade tree used in coastal dry locations Erosion control throughout arid and semi-arid areas | Low Water Requirements Attractive feathery foliage A shade tree controlling erosion throughout arid and semi-arid areas Easily transplanted Long living plant, 110-120 years | Prune regularly, High Maintenance Considered a weed in some countries | Recommend | Buffer to eliminate access to zone 1 Offers shading for users Low Water Requirement |
| SHRUBS | | | | | | |
| Clerodendrum inerme | ياسمين زفر | A climber on fences, trellises, retaining walls and roots; cultivated as a groundcover for sand dune stabilizing A border in public and house gardens; easy to trim and shape | Sand dune stabilizing Easy to trim and shape Long living plant, 50-60 years | | Recommend | Buffer to eliminate access to zone 1 Easy trim and shape Low Water Requirement |
| Dichrostachys cinerea (L.) Wight & Arn. | دیکروستاشیس | Buffers and fences Widely used for soil conservation Edible fruits, seeds and flowers with medicinal values | Blooming 6 months Sep-Feb Long Living plant, 40-50 years | | High Recommended | Buffer to eliminate access to zone 1 Long flowering season Attractive Ornamental features Moderate Water requirements |
| Lawsonia inermis L. | حنة بلدی | A hedge or used in shrub borders Source of henna (an orange hair dye used since pharaonic ages) Medicinal properties | Aromatic Flower Historical Pharaonic Henna, could be sold in the park Medium living plant, 30-40 years, Low maintenance | | H. Recommended | Buffer to eliminate access to zone 1 Attractive Aromatic Ornamental shrub Moderate Water requirements |
| Climbers | | | | | | |
| Bougainvillea Stans | جهنمية أفرنجی | Climbing or Shrubby-shaped flowering plant, which covers arches, pergolas and fences Can serve as hedge if properly trimmed | Blooming all year Attractive colors | Requires trimming Frost-intolerant Hard to transplant | Recommend | Everblooming Colorful hedge and barrier border |
| Ipomoea pes-caprae (L.) R.Br. | ایبوما خف الجمل | An ornamental climbing plant that can be used as a groundcover on excessively dry soils and along coastal areas Soil-stabilizer and control erosion on slopes | Groundcover on excessively dry soils and along coastal areas Soil-stabilizer and control erosion on slopes Shelter from cold drying wind | Seeds are toxic Deciduous plant Hard to transplant after it is 1.5 m long | Recommend | Ornamental climbing plant Away from user's contact |
| Solanum seaforthianum Andrews | سولاتم، سیفورسیانم | Used in gardens as vines, subshrubs, shrubs or small trees for their large, night-scented flowers Gardens edges and pergolas | Blooms almost all year Large, night-scented flowers Flowers have attractive 5 reflected lobes | Poisonous to humans Hard to transplant after it is 1.5 m long | H. Recommended | Ornamental plant Night-scented flowers Away from user's contact |
| Groundcovers | | | | | | |
| Alternanthera species | آلترانتیرا حمراء أو خضراء | Excellent for borders, beds, edging of large areas, as a house plant and in hanging baskets Grown for their multi-colored foliage Spaced 10 cm or 30 cm apart for carpet effect as groundcover | Grown for their multi-colored foliage Full sun and warm places allow for best leaf color | Flower only 2 months Frost intolerant | Recommend | Buffer to eliminate access to zone 1 Offers shading for users Moderate Water Requirement |
| Anemone species | أنیمون | Favorite Park and rock garden plant Used in flower beds, cut flower, in container and a groundcover for large areas In medicine as a treatment cramp | Easily transplanted Very free flowering groundcover forms large colony Flowers produced singly with 4-27 sepals in cymes of 2-9 flowers Sepals with various colors | Sap causes irritation to skin Low wind tolerance | Recommend | Buffer to eliminate access to zone 1 Ornamental plant Away from user's contact |
| Mentha spicata L. | نعناع | A fragrant, low groundcover herb popular in Egyptian gardens for culinary and medicinal uses, especially in semi-shady spots Rock gardens, borders, muddy edges, and slope stabilizer | Popular in Egypt for culinary and medicinal uses Slope Stabilizer Easily transplanted Humidity and pollution tolerant | Invasive Plant | Recommend | Buffer to eliminate access to zone 1 Ornamental plant Semi shaded areas |

Zone 3

| | | |
|--------|-----------------------|--|
| Zone 3 | Water Pathway: | Free-Surface Wetland (1m depth, 0.25 m gravel and 0.5 m water above) |
| | Vegetation: | Ornamental and Aromatic Aquatic at Water Pathway |
| | Theme Purpose: | Bloom: Long blooming period Ornament: Attractive Ornamental features Suitable for public recreational spaces Water: Moderate Water Requirement |

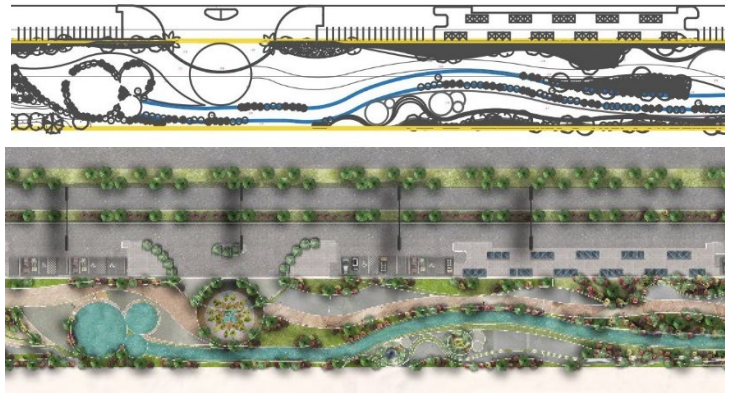


Table (32) Selected species for zone 3, Source: Author

| Latin Name | Name in Arabic | Design Use and Value مجالات استخدام النبات في التصميم | ايجابية أو سلبية ملاحظات | | Selection | Reason of Selection |
|---|--|--|---|---|----------------|--|
| | | | Positive | Negative | | |
| PALMS | | | | | | |
| Hyphaene thebaica (L.) Mart. | نخيل الدوم | Along riverbanks to stabilize soil and control erosion Leaves provide raw materials used in basketry in upper Egypt Fruits are used for food, beverage and medicinal applications | Tolerates temperate climate Considered sacred by ancient Egyptians | Very difficult to transplant | Check | Stabilize soil and control erosion |
| Phoenix dactylifera L. | نخيل البلح | An ornamental shade and street palm when planted at close intervals Planted mainly for its edible fruits, timber and fronds | An ornamental shade a Long living plant, 80-100 years Easily transplanted | Requires extra water for better fruit production Risk of people eating fruit | Recommended | Ornamental Plant Offers shading for users |
| TREES | | | | | | |
| Acacia nilotica | أكاسيا نيلوتيك، السنط، شوكة مصرية، القرض | Popular desert landscape plant in parks and garden A hedge, a shade tree or used along rivers and water channels A source of wood, fuel, and medicine | A hedge, a shade tree or used along rivers and water channels Long living plant, 80-100 years | | Recommended | Shade along Water channel |
| Bauhinia variegata | خف الجمل | Ornamental specimen, valued for its flowers and shade Popular in parks, gardens, and streets | Ornamental aesthetic colorful tree Attractive shading tree Easily transplanted | | Recommended | Offers shading for users Attractive ornamental colorful tree Moderate Water Requirement |
| Cassia nodosa | كاسيا ندوزا، العشرقي | Extremely ornamental shade tree in open lawn areas and parks Excellent shades at wide sidewalks of major streets Attractive for its spreading canopy and long flowering season Very attractive, aromatic. Bright pink flowers | Blooming 5 months Attractive colorful shading tree Ornamental impressive tree, striking in full bloom Long living plant, 40-50 years | | H. Recommended | Long Flowering period Attractive Ornamental features Moderate Water requirements |
| Delonix regia (Bojer ex Hook.) Raf. | بوانسيانا | Extremely ornamental specimen tree in gardens and parks Good Shades in roadside and urban planting Striking in full bloom; impressive when planted in groups | Blooming 5 months Attractive colorful shading tree Ornamental impressive tree, striking in full bloom Long living plant, 50-60 years | | H. Recommended | Long Flowering period Attractive Ornamental features Moderate Water requirements |
| prosopis juliflora | بروسويس، الغاف | Ornamental tree, used to control erosion, stabilize sand dunes and as a windbreak or high screen Flowers are used to make honey and wood is used in grilling | Low Water requirements Used to control erosion, stabilize sand dunes and as a windbreak or high screen Long living plant, 90-100 years | | Recommended | Attractive Ornamental features Low Water requirements |
| SHRUBS | | | | | | |
| Abutilon species | أبو تيلون | Planted against warm walls as shrub border A house plant in large containers Seeds are used in traditional medicine | Blooming 6 months Ornamental Plant Pleasing Highly colored Medium living plant, 30-40 years | | H. Recommended | Long flowering season Attractive Ornamental features Moderate Water requirements |
| Cassia didymobotrya Syn. Senna | سنا صفراء | A specimen shrub Integrated in plant companions, especially in flower beds | Blooming 4 months Aromatic Flower and Leaf Long living plant, 50-60 years | | Recommended | Long flowering season Attractive Ornamental features Moderate Water requirements |
| Dichrostachys cinerea (L.) Wight & Arn. | ديكروستاشيس | Buffers and fences Widely used for soil conservation Edible fruits, seeds and flowers with medicinal values | Blooming 6 months Sep-Feb Long Living plant, 40-50 years | | H. Recommended | Buffer to eliminate access to zone 1 Long flowering season Attractive Ornamental features Moderate Water requirements |
| Gladiolus species | جلاديلوس | Very attractive in clumps of mixed borders Pots and containers Excellent cut flowers | Very attractive colorful flowers | Short living plant, only one-year, High Maintenance | Check | Attractive Ornamental features Cut flower in public spaces Moderate Water requirements |
| Jasminum sambac | الفل | An ornamental plant Often grown in pots in patio or deck in summer Culinary usage in form of the jasmine tea | Blooming 6 months Ornamental Plant Pleasing Aroma, Flower Aroma | Short living plant, 7-10 years, Medium Maintenance Slow growth rate | H. Recommended | Long flowering season Attractive Aromatic Ornamental features Moderate Water requirements |
| Lawsonia inermis L. | حنة بلدي | A hedge or used in shrub borders Source of henna (an orange hair dye used since pharaonic ages) Medicinal properties | Aromatic Flower Historical Pharaonic Henna, could be sold in the park Medium living plant, 30-40 years, Low maintenance | | H. Recommended | Buffer to eliminate access to zone 1 Attractive Aromatic Ornamental features Moderate Water requirements |
| Pentas lanceolata Syn. P. carnea | بنتاس | Grown for their showy flowerheads Beds and borders in parks, gardens, and courts Pots, baskets and containers | Blooming 4 months Showy flowerheads | Short living plant, 3-5 years, High Maintenance | H. Recommended | Long flowering season Attractive Ornamental features Moderate Water requirements |
| Vitex agnus-castus L. | فاينكس أخضر | An ornamental specimen tree, planted along rivers and ponds Shrub border against walls Medicinal usage | Aromatic Flower Attractive foliage and flowers Medium living plant, 20-30 years | | H. Recommended | Attractive Aromatic Ornamental features Moderate Water requirements |

Table (33) Selected species for zone 3 (Cont'd)

| Latin Name | Name in Arabic | Design Use and Value مجالات استخدام النبات في التصميم | ايجابية أو سلبية ملاحظات | | Selection | Reason of Selection |
|---|--------------------------------|--|--|--|----------------|---|
| | | | Positive | Negative | | |
| Climbers | | | | | | |
| Bougainvillea Stans | جهنمية أفريقي | Climbing or Shrubby-shaped flowering plant, which covers arches, pergolas and fences Can serve as hedge if properly trimmed | Blooming all year Attractive colors | Requires trimming Frost-intolerant Hard to transplant after it is 1.5 m long | H. Recommended | Everblooming Colorful hedge and barrier border |
| Clerodendrum splendens | كبرياء طربوش الملك | A climber for fences, trellises, balconies, terraces and roofs Cultivated for their foliage and long flowering seasons Public and house gardens | Blooming 6 months Cultivated for their foliage and long flowering seasons | Become invasive by suckering Hard to transplant after it is 1.5 m long | H. Recommended | Long flowering season Cultivated foliage in public spaces Moderate Water requirements |
| Clerodendrum thomsoniae | كرمة القلب الدامي | A climber, a shrub or a groundcover, for fences, trellises, balconies, terraces and roofs Cultivated in public and private gardens in warmer locations for their foliage and flowers | Beautiful flower Cultivated in public and private gardens in warmer locations for their foliage and flowers | Hard to transplant after it is 1.5 m long | H. Recommended | Ornamental beautiful flower Cultivated foliage in public spaces Moderate Water requirements |
| Stephanotis floribunda | ستيغانوتيس | A climber for fences, trellises, balconies, terraces and roofs Grown for their strongly perfumed flowers Public, private gardens and borders | Blooming 6 months Strongly perfumed flowers | Hard to transplant after it is 1.5 m long | H. Recommended | Long flowering season Ornamental beautiful flower Strongly perfumed in public spaces |
| Groundcovers | | | | | | |
| Achillea millefolium | أشيليا، ألف زهرة | An ornamental plant with attractive flowers Excellent for beds and borders The entire plant is used in folk and pharmaceutical medicine | Attractive flowers in various colors In warm locations flowers exist almost all year round Useful entire plant | Hard to transplant | H. Recommended | Ornamental at Park's entrance and public space Entire useful Plant |
| Alternanthera species | ألفرنانتيرا حمراء أو خضراء | Excellent for borders, beds, edging of large areas, as a house plant and in hanging baskets Grown for their multi-colored foliage Spaced 10 cm or 30 cm apart for carpet effect as groundcover | Grown for their multi-colored foliage Full sun and warm places allow for best leaf color | Flower only 2 months Frost intolerant | H. Recommended | Buffer to eliminate accessibility to zone 1 Offers shading for users Moderate Water Requirement |
| Anemone species | أنيمون | Favorite park and rock garden plant Used in flower beds, cut flower, in container and a groundcover for large areas In medicine as a treatment cramps | Easily transplanted Very free flowering groundcover that forms a large colony Flowers produced singly with 4-27 sepals in cymes of 2-9 flowers Sepals with various colors | Sap causes irritation to skin Low wind tolerance | H. Recommended | Buffer to eliminate accessibility to zone 1 Ornamental plant Away from user's contact |
| Portulaca grandiflora | رجلة صبار الزهور | Beautiful groundcover in rocky, dry and south facing slopes Ornamental plant for bedding, borders, edging, containers, hanging baskets, in cracks of rock walls and steps | Blooming 4 months Attractive colorful flowers (Red, orange, white and yellow) Flowers open only during bright sunlight; closing at night and on cloudy days Numerous cultivars provide double flowers with additional petals and colors | | H. Recommended | Long flowering season Attractive Ornamental features Moderate Water requirements |
| Verbena hybrida | فربيينا بلدي، فربيينا إنجليزية | Ideal for garden borders and edging Used in beds and containers | Blooming all year Multi-colored flowers, sometimes scented . Easily transplanted | Short living plant, 1-2 years | H. Recommended | Everblooming Plant Colorful scented plant at public space and recreational area |
| Ornamental Grasses | | | | | | |
| Cortaderia selloana (Schult. & Schult.f.) Asch. & Graebn. | حشيشة كورتديريا | One of the most recognized plants in the landscape Used in fresh or dried flower arrangements Grows at the back of a border | Attractive Silky, silvery, often pink-purple flushed spikelets Easily transplanted | Plant has sharp edges and spines Loses flowers if not watered regularly | H. Recommended | Ornamental at Park's entrance and public space Moderate Water requirements |
| Miscanthus sinensis Andersson | حشيشة الميكانتاس | A nice mass of textured foliage, a specimen, screen, in rock gardens, edging borders Suitable for cut or dry flowers In masses with other ornamental grasses Great near ponds | Attracts birds and butterflies, Biodiversity Easily transplanted | Cut back to the ground in the Spring Short living plant, 7-9 years | H. Recommended | Ornamental at Park's entrance and public space Biodiversity Low water requirements |
| Paspalum vaginatum Sw. | باسيالم سي شور، نجيل | A groundcover for extended lawn areas and public spaces in gardens and parks Successful at coastal areas Control erosion in sandy areas | Blooming 6 months Paspalum 10, 8, 4 are commonly used in Egypt, Mow at 2-2.5 cm Control erosion in sandy areas Easily transplanted | Short living plant, 5-7 years | H. Recommended | Long flowering season Ornamental at Park's entrance and public space |

Zone 4

| | |
|-----------------------|--|
| Water Pathway: | Pond & Fountain |
| Vegetation: | Biodiversity Aesthetic and Shading |
| Theme Purpose: | Biodiversity: Attractive to different Fauna Species Public Use: Vegetations are user-safe Water: Moderate Water Requirement |

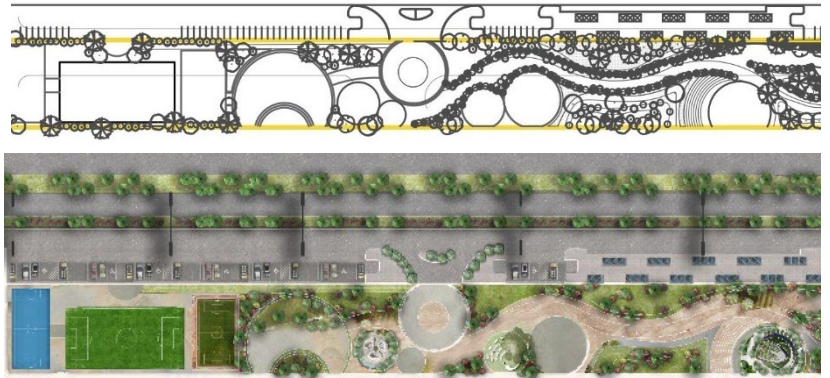


Table (34) Selected species for zone 4, Source: Author

| Latin Name | Name in Arabic | Design Use and Value مجالات استخدام النبات في التصميم | ايجابية أو سلبية ملاحظات | | Selection | Reason of Selection |
|--|--|--|--|--|--------------|---|
| | | | Positive | Negative | | |
| PALMS | | | | | | |
| Hyphaene thebaica (L.) Mart. | نخيل الدوم | Along riverbanks to stabilize soil and control erosion Leaves used as raw materials in basketry in upper Egypt Fruits are used for food, beverage and medicinal applications | Tolerates temperate climate Considered sacred by ancient Egyptians | Very difficult to transplant | Check | Stabilize soil and control erosion |
| Phoenix dactylifera L. | نخيل البلح | An ornamental shade and street palm when planted at close intervals Planted mainly for its edible fruits, timber, and fronds | An ornamental shade a Long living plant, 80-100 years Easily transplanted | Requires extra water for better fruit production Risk of people eating fruit | Recommend | Ornamental Plant Offers shading for users |
| TREES | | | | | | |
| Acacia nilotica | أكاسيا نيلوتিকা، السنط، شوكة، مصرية، القرض | Popular desert landscape plant in parks and garden A hedge, a shade tree or used along rivers and water channels A source of wood, fuel and medicine | A hedge, a shade tree or used along rivers and water channels Long living plant, 80-100 years | | Recommend | Shade along Water channel |
| Bauhinia variegata | خف الجمل | Ornamental specimen, valued for its flowers and shade Popular in parks, gardens, and streets | Ornamental aesthetic colorful tree Attractive shading tree Easily transplanted | | Recommend | Offers shading for users Attractive ornamental colorful tree Moderate Water Requirement |
| Cassia nodosa | كاسيا ندوزا، العشرقي | Extremely ornamental shade tree in open lawn areas and parks Excellent shades at wide sidewalks of major streets Attractive for its spreading canopy and long flowering season Very attractive, aromatic. Bright pink flowers | Blooming 5 months Attractive colorful shading tree Ornamental impressive tree, striking in full bloom Long living plant, 40-50 years | | H. Recommend | Long Flowering period Attractive Ornamental features Moderate Water requirements |
| Erythrina crista-galli L. | شجرة المرجان | Ornamental small-mid size tree Used in parks and botanical gardens Edible fruits in September | Blooming 6 months Medium living plant, 20-25 years | | H. Recommend | Long Flowering period Offers shading for users Moderate Water Requirement |
| Ficus sycomorus L. | الجميز | A shade tree in parks, gardens and streets Air purification with edible fruits and hard wood A landmark in Egyptian countryside landscape | Air purification, fast growing shade tree A landmark in Egyptian landscape Long living plant, 150-160 years | Risk of people eating fruit Hard to transplant | H. Recommend | Air purification Vegetation is user-safe |
| Pongamia pinnata (L.) Pierre | بونجاميا | Fine shade and ornamental tree; planted frequently in parks, gardens, and streets. Suitable for coastal gardens Oil production | Nitrogen fixing tree Long living plant, 50-70 years Easily transplanted | Requires pruning | Check | Offers shading for users Air purification Vegetation is user-safe |
| Ziziphus spina-christi (L.) Desf. | النبق، السدر | Fruit tree with ornamental value Local Egyptian flora tree used as a windbreak and hedge Stabilize sand dunes and stop erosion | Aromatic Local Egyptian flora tree Used as a windbreak and hedge Stabilize sand dunes and stop erosion Long living plant, 80-90 years | Risk of people eating fruit | Recommend | Attractive Ornamental features Aromatic plant Moderate Water requirements |
| SHRUBS | | | | | | |
| Barleria cristata | بارليريا | A superior hedge, foundation, or border Good specimen Shaded rocky gardens | Attracts birds and insects; Biodiversity Easy to maintain and to transplant Medium living plant, 10-15 years | | Recommend | Long Flowering period Attractive to different Fauna Species Blooming 4 months |
| Caesalpinia pulcherrima (L.) Sw. | سيزالبينيا | A beautiful specimen and cluster plant when placed in large lawn areas in domestic and public desert gardens Medicinal usage | Wide spreading branches Attracts hummingbirds and bees; Biodiversity | Poisonous Hard to transplant | Recommend | Long Flowering period Attractive to different Fauna Species Blooming 4 months |
| Carissa grandiflora | كاريسا جرانديفلورا | An attractive shrub border or a hedge Very successful along coastal areas Fruits are used to make jam and dyes | Blooms 4 months Low water requirements High Tolerance, Easily transplanted Aromatic Flower and Attractive shrub | | Check | Long Flowering period Attractive Ornamental features Vegetation is user-safe |
| Euphorbia continifolia | ايغوربيا حمراء، بنت القنصل الحمراء | Attractive shrub or small tree Used for its red leaves and exotic white flowers | Medium living plant, 25-30 years | | Recommend | Attractive Ornamental features Moderate Water requirements |
| Euphorbia pulcherrima | بنت القنصل | Highly attractive specimen in parks and gardens An ornamental house plant specially in Christmas season A regular pot plant | Highly attractive Could be sold in the park in Christmas season Medium living plant, 30-50 years | | H. recommend | Attractive Ornamental features Moderate Water requirements |
| Hibiscus sabdariffa L. | كركديه | An ornamental plant especially in Upper Egypt Roselle fruits are harvested fresh and calyces are made into a drink rich in vitamin C (Hibiscus tes). Medicinal uses. | Tolerates Floods, but Frost-intolerant Easily transplanted | Mainly planted for food | Check | Ornamental Plant Vegetation is user-safe |
| Hibiscus rosa-sinensis | هيبسكس أحمر | Ideal Outstanding specimen in gardens and parks for its showy flowers and rich foliage Used in hedges, clustered groups , borders and mass planting | Blooming 4 months Showy flowers and rich foliage Fast growth rate | Medium living plant, 7-10 years, Medium Maintenance | H. Recommend | Long Flowering period |
| Lantana camara | لاتنانا كامارا | Forms hedges in gardens, parks and streets Ideally planted against sunny walls Can be used as shrub or groundcover | Blooming 4 months Aromatic Flower and leaf Attracts butterflies and bees, Biodiversity Easily transplanted | Pruning is needed Aggressive Plant Poisonous fruits if eaten green | Recommend | Long Flowering period Attractive to different Fauna Species Aromatic Plant |
| Lanvandula angustifolia Syn. L. officinalis | لافندر | Aromatic subshrub, useful for edging and as a low hedge Leaves and spikes are used to produce perfume oil, potpourri and in herbal medicine | Aromatic Flower and leaf Attract butterflies and bees; Biodiversity Economical benefits of selling perfume oil | Short living, 2-3 years, High maintenance | Recommend | Aromatic Plant Attractive to different Fauna Species |
| Ocimum basilicum | ريحان | Grows among early-blooming plants in borders Culinary herb, in vegetable, herb and rock gardens Medicinal usage | Aromatic Flower and Leaf | Short living plant, 1-2 years, High Maintenance | Check | Aromatic Plant Vegetation is user-safe |
| Salvia rosmarinus Spenn. | روز ماري، حصا لبنان | Used in shrub or mixed borders in herb or rock gardens Against a sunny wall or as a hedge in desert landscape Culinary purposes | Aromatic Flower and leaf | Short living plant, 4-7 years, High Maintenance Risk of people using the leaves | Check | Aromatic Plant Vegetation is user-safe |

Table (35) Selected species for zone 4 (Cont'd)

| Latin Name | Name in Arabic | Design Use and Value مجالات استخدام النبات في التصميم | إيجابية أو سلبية ملاحظات | | Selection | Reason of Selection |
|---|--------------------|--|--|--|----------------|---|
| | | | Positive | Negative | | |
| | | | | | | |
| Climbers | | | | | | |
| Bougainvillea Stans | جهنمية أفرنجى | Climbing or Shrubby-shaped flowering plant, which covers arches, pergolas, and fences Can serve as hedge if properly trimmed | Blooming all year Attractive colors | Requires trimming Frost-intolerant Hard to transplant after it is 1.5 m long | H. Recommended | Everblooming Colorful hedge and barrier border |
| Jasminum grandiflorum subsp. floribundum (R.Br. ex Fresen.) P.S.Green | ياسمين بلدى | Twine over any suitable support, a trellis, fence, arch, or as a large shrub in gardens, parks, and rock gardens Perfume and medicine manufacture | Blooming 4 months Aromatic Flower Attracts birds and butterflies, Biodiversity | Frost-intolerant Deciduous plant Hard to transplant after it is 1.5 m long | H. Recommended | Long Flowering period Attractive to different Fauna Species Aromatic |
| Groundcovers | | | | | | |
| Lantana camara nana | لائتانا صفراء | An ornamental groundcover plant Used as specimen in low hedges, beds, and borders | Blooming 4 months Aromatic Flower and Leaf Attracts butterflies and bees, Biodiversity Easily transplanted | Pruning is needed Aggressive Plant Poisonous fruits | H. Recommended | Everblooming Colorful Aromatic plant at public space and recreational area |
| Lantana montevidensis | لائتانا زرقاء | An ornamental groundcover plant Used as specimen in low hedges, beds, and borders | Blooming 4 months Aromatic Flower and Leaf Attracts butterflies and bees, Biodiversity Easily transplanted | Pruning is needed Aggressive Plant Poisonous fruits Short living plant, 5-7 years | H. Recommended | Long Flowering period Attractive to different Fauna Species |
| Origanum vulgare Syn. Origanum majorana | بردقوش | Suitable for small border, contrasting with green shrubs Aromatic perennial herb Oil used for seasoning and seeds are medicinal | Aromatic perennial herb Oil used for seasoning and seeds are medicinal Attracts butterflies and bees, Biodiversity Easily transplanted | Deadhead in early spring | H. Recommended | Attractive to different Fauna Species Aromatic Plant Vegetation is user-safe |
| Pelargonium peltatum | جارونيا لير، مدادة | Excellent groundcover under large trees, on trellis, to cascade down terraced or retaining walls in coastal areas A container and hanging basket plant. Easy to look after | Blooming 7 months Excellent groundcover under large trees Easy to look after, Low maintenance Tolerates poor soils, easily transplanted, Frost-hardy Attracts butterflies and bees, Biodiversity | Short living plant, 2-3 years | H. Recommended | Long Flowering period Attractive to different Fauna Species Semi Shaded; Under large trees |
| Tagetes erecta | القطيفة | Used for bedding and edges of mixed borders, in parks and gardens | Blooming all year Aromatic Flower and Leaf Attracts butterflies and bees, Biodiversity Seeds in any season, Large double flowerheads Easily transplanted | Short living plant, 1-2 years | H. Recommended | Attractive to different Fauna Species Everblooming Colorful Aromatic plant at public space and recreational area |

4. Vegetation According to Blooming Seasons

Table (36) Selected species according to Blooming seasons and color scheme

| Latin Name | Name in Arabic | شهور التزهير Bloom | | | | | | | | | | | | Selection | Zone | Type |
|---|-----------------------------------|--------------------|---|---|---|---|---|---|---|---|----|----|----|----------------|------|--------------------|
| Bougainvillea Stans | جهنمية أفرنجى | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | H. Recommended | 1-4 | Climbers |
| Lantana camara nana | لاتناتا صفراء | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | H. Recommended | 4 | Groundcovers |
| Tagetes erecta | القطيفة | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | H. Recommended | 4 | Groundcovers |
| Verbena hybrida | فربيينا بلدى، فربيينا إنجليزى | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | H. Recommended | 3 | Groundcovers |
| Euphorbia milii var. splendens | شوكة المسيح | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | H. Recommended | 1 | Succulents & Cacti |
| Gladiolus species | جلاديولس | 1 | 2 | 3 | | | | | | | | | | Check | 3 | Shrubs |
| Clerodendrum splendens | كثيراء طربوش الملك | 1 | 2 | | | | 6 | 7 | 8 | | | | 12 | H. Recommended | 3 | Climbers |
| Bauhinia variegata | خف الجمل | | 2 | 3 | 4 | | | | | | | | | Recommended | 3-4 | Trees |
| Clerodendrum thomsoniae | كروية القلب الداى | | 2 | 3 | 4 | | | | | | | | | Recommended | 3 | Climbers |
| Solanum seafortianum Andrews | سولانم، سيفورسيانم | | | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | | | H. Recommended | 2 | Climbers |
| Pelargonium peltatum | جارونيا لير، مدادة | | | 3 | 4 | 5 | 6 | | | 9 | 10 | 11 | | H. Recommended | 4 | Groundcovers |
| Achillea millefolium | أشيليا ألف زهرة | | | 3 | 4 | 5 | | | | | | | | H. Recommended | 3 | Groundcovers |
| salix babylonica | صفصاف أم الشعور، الصمصام الباكى | | | 3 | 4 | | | | | | | | | H. Recommended | 2 | Trees |
| Erythrina crista-galli L. | شجرة المرجان | | | | 4 | 5 | 6 | 7 | 8 | 9 | | | | H. Recommended | 4 | Trees |
| Jasminum sambac | الفل | | | | 4 | 5 | 6 | 7 | 8 | 9 | | | | H. Recommended | 3 | Shrubs |
| Delonix regia (Bojer ex Hook.) Raf. | بوانسيانا | | | | 4 | 5 | 6 | 7 | 8 | | | | | H. Recommended | 3 | Trees |
| Abutilon species | أبو تيلون | | | | 4 | 5 | 6 | 7 | 8 | | | | | H. Recommended | 3 | Shrubs |
| Albizia lebbeck (L.) Benth. | اللبخ، دقن الباشا | | | | 4 | 5 | 6 | | | | | | | Recommended | 2 | Trees |
| Anemone species | أنيمون | | | | 4 | 5 | 6 | | | | | | | Recommended | 2-3 | Groundcovers |
| Erythrina caffra | إرثرينا كفرا | | | | 4 | 5 | | | | | | | | Recommended | 2 | Trees |
| Sedum acre | سديم | | | | 4 | 5 | | | | | | | | H. Recommended | 1 | Succulents & Cacti |
| Phoenix dactylifera L. | نخيل البلخ | | | | 4 | | | | | | | | | Recommended | 1-4 | Palms |
| Paspalum vaginatum Sw. | باسپالم سى شور، نخيل | | | | | 5 | 6 | 7 | 8 | 9 | 10 | | | H. Recommended | 3 | Ornamental Grasses |
| Barleria cristata | بارليريا | | | | | 5 | 6 | 7 | 8 | | | | | Recommended | 4 | Shrubs |
| Caesalpinia pulcherrima (L.) Sw. | سيزالپينيا | | | | | 5 | 6 | 7 | 8 | | | | | Recommended | 4 | Shrubs |
| Carissa grandiflora | كاريسا جرانديفلورا | | | | | 5 | 6 | 7 | 8 | | | | | Check | 4 | Shrubs |
| Cassia didymobotrya Syn. Senna | سنا صفراء | | | | | 5 | 6 | 7 | 8 | | | | | Recommended | 3 | Shrubs |
| Hibiscus rosa-sinensis | هيبسكس أحمر | | | | | 5 | 6 | 7 | 8 | | | | | H. Recommended | 4 | Shrubs |
| Lantana camara | لاتناتا كامارا | | | | | 5 | 6 | 7 | 8 | | | | | Recommended | 4 | Shrubs |
| Pentas lanceolata Syn. P. carnea | بنثاس | | | | | 5 | 6 | 7 | 8 | | | | | H. Recommended | 3 | Shrubs |
| Lantana montevidensis | لاتناتا زرقاء | | | | | 5 | 6 | 7 | 8 | | | | | Recommended | 4 | Groundcovers |
| Calotropis procera (Aiton) W.T.Aiton | العشار، الغشتر | | | | | 5 | 6 | 7 | 8 | | | | | Check | 1 | Succulents & Cacti |
| Sesbania sesban Syn. S. argyptiacia | السسيان، البان | | | | | 5 | 6 | 7 | | | | | | Recommended | 2 | Trees |
| Crassula hottentot | كراسولا السيحة | | | | | 5 | 6 | 7 | | | | | | Recommended | 1 | Succulents & Cacti |
| Hyphaene thebaica (L.) Mart. | نخيل الدوم | | | | | 5 | 6 | | | | | | | Check | 1-4 | Palms |
| Acacia nilotica | أكاسيا نيلوتيك، السنط، شوكة مصرية | | | | | 5 | 6 | | | | | | | Recommended | 1-4 | Trees |
| Pongamia pinnata (L.) Pierre | بونجاميا | | | | | 5 | 6 | | | | | | | Check | 4 | Trees |
| Ziziphus spina-christi (L.) Desf. | النقي، السدر | | | | | 5 | 6 | | | | | | | Recommended | 4 | Trees |
| Salvia rosmarinus Spenn. | روز ماري، حصا لبان | | | | | 5 | 6 | | | | | | | Check | 4 | Shrubs |
| Cassia nodosa | كاسيا ندوزاء العشرى | | | | | | 6 | 7 | 8 | 9 | 10 | | | H. Recommended | 3-4 | Trees |
| Jasminum grandiflorum subsp. floribundum | ياسمين بلدى | | | | | | 6 | 7 | 8 | 9 | | | | H. Recommended | 4 | Climbers |
| Portulaca grandiflora | رجلة صبار الزهور | | | | | | 6 | 7 | 8 | 9 | | | | H. Recommended | 3 | Groundcovers |
| Mesembryanthemum cordifolia Syn. Aptenia | أبتنيا | | | | | | 6 | 7 | 8 | 9 | | | | H. Recommended | 1 | Succulents & Cacti |
| Cestrum ayrautiacum Syn. C. chaculanum | مسك الليل | | | | | | 6 | 7 | 8 | | | | | H. Recommended | 1 | Shrubs |
| Cestrum elegans | ملكة الليل | | | | | | 6 | 7 | 8 | | | | | Recommended | 1 | Shrubs |
| Clerodendrum inerme | ياسمين زفر | | | | | | 6 | 7 | 8 | | | | | Recommended | 2 | Shrubs |
| Lawsonia inermis L. | حنة بلدى | | | | | | 6 | 7 | 8 | | | | | H. Recommended | 2-3 | Shrubs |
| Ocimum basilicum | ريحان | | | | | | 6 | 7 | 8 | | | | | Check | 4 | Shrubs |
| Vitex agnus-castus L. | فايتكس أخضر | | | | | | 6 | 7 | 8 | | | | | H. Recommended | 3 | Shrubs |
| Adenium obesum Syn. A. arabicum | جوافة زهور | | | | | | 6 | 7 | 8 | | | | | H. Recommended | 1 | Succulents & Cacti |
| Cordia myxa L. | شجرة المخيط | | | | | | 6 | 7 | | | | | | H. Recommended | 2 | Trees |
| prosopis juliflora | بروسويس، الغاف | | | | | | 6 | 7 | | | | | | Recommended | 3 | Trees |
| Hibiscus sabdariffa L. | كركدية | | | | | | 6 | 7 | | | | | | Check | 4 | Shrubs |
| Alternanthera species | ألترانثيرا حمراء أو خضراء | | | | | | 6 | 7 | | | | | | Recommended | 2-3 | Groundcovers |
| Stephanotis floribunda | ستيفانوتس | | | | | | | 7 | 8 | 9 | 10 | 11 | 12 | H. Recommended | 3 | Climbers |
| Lanvandula angustifolia Syn. L. officinalis | لافندر | | | | | | | 7 | 8 | 9 | | | | Recommended | 4 | Shrubs |
| Ipomoea pes-caprae (L.) R.Br. | إيبوما خف الجمل | | | | | | | 7 | 8 | 9 | | | | Recommended | 2 | Climbers |
| Yucca filamentosa | يوكا أبرية | | | | | | | 7 | 8 | 9 | | | | H. Recommended | 1 | Succulents & Cacti |
| Ficus sycomorus L. | الجميز | | | | | | | 7 | 8 | | | | | H. Recommended | 4 | Trees |
| Tamarix aphylla (L.) H.Karst. | الطرفة | | | | | | | 7 | 8 | | | | | Recommended | 2 | Trees |
| Mentha spicata L. | نعناع | | | | | | | 7 | 8 | | | | | Recommended | 2 | Groundcovers |
| Thymus vulgaris | زعتة جبلى | | | | | | | 7 | 8 | | | | | Recommended | 1 | Groundcovers |
| Origanum vulgare Syn. Origanum majorana | بردقوش | | | | | | | | 8 | 9 | | | | Recommended | 4 | Groundcovers |
| Cortaderia selloana Asch. & Graebn. | حشيشة كورتديريا | | | | | | | | 8 | 9 | | | | H. Recommended | 3 | Ornamental Grasses |
| Cymbopogon citratus (DC.) Stapf | حشيشة الليمون | | | | | | | | 8 | 9 | 10 | | | Check | 1 | Ornamental Grasses |
| Miscanthus sinensis Andersson | حشيشة الميكانتاس | | | | | | | | 8 | 9 | 10 | | | Recommended | 3 | Ornamental Grasses |
| Dichrostachys cinerea (L.) Wight & Arn. | ديكروستاشيس | 1 | 2 | | | | | | | 9 | 10 | 11 | 12 | H. Recommended | 2-3 | Shrubs |
| Euphorbia continifolia | أيفوريا حمراء، بنت القنصل الحمراء | 1 | | | | | | | | | | 12 | | Recommended | 4 | Shrubs |
| Euphorbia pulcherrima | بنت القنصل | 1 | | | | | | | | | | 12 | | H. Recommended | 4 | Shrubs |

Zone 1

Table (37) Selected species according to Blooming seasons and color scheme for zone 1, Source: Author

| No | Latin Name | Name in Arabic | Bloom شهيرات | | | | | | | | | | | | Selection | |
|----|--|--|--------------|---|---|---|---|---|---|---|---|----|----|----|----------------|--------------------|
| 1 | Bougainvillea Stans | جهنمية أفرنجى | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | H. Recommended | Climbers |
| 2 | Euphorbia milii var. splendens | شوكية المسح | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | H. Recommended | Succulents & Cacti |
| 3 | Sedum acre | سيدم | | | | 4 | 5 | | | | | | | | H. Recommended | Succulents & Cacti |
| 4 | Phoenix dactylifera L. | نخيل البلح | | | | 4 | | | | | | | | | Recommended | Palms |
| 5 | Calotropis procera (Aiton) W.T.Aiton | العشار، الغش | | | | | 5 | 6 | 7 | 8 | | | | | Check | Succulents & Cacti |
| 6 | Crassula hottentot | كراسولا السبحة | | | | | 5 | 6 | 7 | | | | | | Recommended | Succulents & Cacti |
| 7 | Hyphaene thebaica (L.) Mart. | نخيل الدوم | | | | | 5 | 6 | | | | | | | Check | Palms |
| 8 | Acacia nilotica | أكاسيا نيلوتيك، السنط، شوكية مصرية، القرض | | | | | 5 | 6 | | | | | | | Recommended | Trees |
| 8 | Mesembryanthemum cordifolia Syn. Aptenia, Litocarpus | أبتنيا | | | | | | 6 | 7 | 8 | 9 | | | | H. Recommended | Succulents & Cacti |
| 10 | Cestrum ayraniticum Syn. C. chaculanum | مسك الليل | | | | | | 6 | 7 | 8 | | | | | H. Recommended | Shrubs |
| 11 | Cestrum elegans | ملكة الليل | | | | | | 6 | 7 | 8 | | | | | Recommended | Shrubs |
| 12 | Adenium obesum Syn. A. arabicum | جواقة زهور | | | | | | 6 | 7 | 8 | | | | | H. Recommended | Succulents & Cacti |
| 13 | Yucca filamentosa | يوكا ابرية | | | | | | | 7 | 8 | 9 | | | | H. Recommended | Succulents & Cacti |
| 14 | Thymus vulgaris | زعتر جبلى | | | | | | | 7 | 8 | | | | | Recommended | Groundcovers |
| 15 | Cymbopogon citratus (DC.) Stapf | حشيشة الليمون | | | | | | | | 8 | 9 | 10 | | | Check | Ornamental Grasses |

Zone 2

Table (38) Selected species according to Blooming seasons and color scheme for zone 2, Source: Author

| No | Latin Name | Name in Arabic | Bloom شهيرات | | | | | | | | | | | | Selection | |
|----|---|--|--------------|---|---|---|---|---|---|---|---|----|----|----|----------------|--------------|
| 1 | Bougainvillea Stans | جهنمية أفرنجى | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | H. Recommended | Climbers |
| 2 | Solanum seaforthianum Andrews | سولاتم، سيفورسيانم | | | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | | | H. Recommended | Climbers |
| 3 | salix babylonica | صفصاف أم الشعور، الصفصاف البابى | | | 3 | 4 | | | | | | | | | H. Recommended | Trees |
| 4 | Albizia lebbeck (L.) Benth. | البيخ، دقن الباشا | | | | 4 | 5 | 6 | | | | | | | Recommended | Trees |
| 5 | Anemone species | أنيمون | | | | 4 | 5 | 6 | | | | | | | Recommended | Groundcovers |
| 6 | Erythrina caffra | إرثرينا كافرا | | | | 4 | 5 | | | | | | | | Recommended | Trees |
| 7 | Phoenix dactylifera L. | نخيل البلح | | | | 4 | | | | | | | | | Recommended | Palms |
| 8 | Sesbania sesban Syn. S. argyptiaca | السبسان، البان | | | | | 5 | 6 | 7 | | | | | | Recommended | Trees |
| 9 | Hyphaene thebaica (L.) Mart. | نخيل الدوم | | | | | 5 | 6 | | | | | | | Check | Palms |
| 10 | Acacia nilotica | أكاسيا نيلوتيك، السنط، شوكية مصرية، القرض | | | | | 5 | 6 | | | | | | | Recommended | Trees |
| 11 | Clerodendrum inerme | ياسمين زفر | | | | | | 6 | 7 | 8 | | | | | Recommended | Shrubs |
| 12 | Lawsonia inermis L. | حنة بلدى | | | | | | 6 | 7 | 8 | | | | | H. Recommended | Shrubs |
| 13 | Cordia myxa L. | شجرة المخيط | | | | | | 6 | 7 | | | | | | H. Recommended | Trees |
| 14 | Alternanthera species | ألترنانثيرا حمراء أو أخضراء | | | | | | 6 | 7 | | | | | | Recommended | Groundcovers |
| 15 | Ipomoea pes-caprae (L.) R.Br. | إيبوما خف الجمل | | | | | | | 7 | 8 | 9 | | | | Recommended | Climbers |
| 16 | Tamarix aphylla (L.) H.Karst. | الطرفه | | | | | | | 7 | 8 | | | | | Recommended | Trees |
| 17 | Mentha spicata L. | نعناع | | | | | | | 7 | 8 | | | | | Recommended | Groundcovers |
| 18 | Dichrostachys cinerea (L.) Wight & Arn. | ديكروستاشيس | 1 | 2 | | | | | | | 9 | 10 | 11 | 12 | H. Recommended | Shrubs |

Zone 3

Table (39) Selected species according to Blooming seasons and color scheme for zone 3, Source: Author

| No | Latin Name | Name in Arabic | Bloom شهور التزهير | | | | | | | | | | | | Selection | |
|----|-------------------------------------|--|--------------------|---|---|---|---|---|---|---|---|----|----|----|----------------|--------------------|
| 1 | Bougainvillea Stans | جهنمية أفرنجى | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | H. Recommended | Climbers |
| 2 | Verbena hybrida | فربيينا بلدى، فربيينا إنجليزى | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | H. Recommended | Groundcovers |
| 3 | Gladiolus species | جلاديولس | 1 | 2 | 3 | | | | | | | | | | Check | Shrubs |
| 4 | Clerodendrum splendens | كلبرا، طريوش الملك | 1 | 2 | | | | 6 | 7 | 8 | | | | 12 | H. Recommended | Climbers |
| 5 | Bauhinia variegata | خف الجمل | | 2 | 3 | 4 | | | | | | | | | Recommended | Trees |
| 6 | Clerodendrum thomsoniae | كرمة القلب الداى | | 2 | 3 | 4 | | | | | | | | | Recommended | Climbers |
| 7 | Achillea millefoliumm | أشيليا، ألف زهرة | | | 3 | 4 | 5 | | | | | | | | H. Recommended | Groundcovers |
| 8 | Jasminum sambac | الفل | | | | 4 | 5 | 6 | 7 | 8 | 9 | | | | H. Recommended | Shrubs |
| 9 | Delonix regia (Bojer ex Hook.) Raf. | بوانسيانا | | | | 4 | 5 | 6 | 7 | 8 | | | | | H. Recommended | Trees |
| 10 | Abutilon species | أبو تيلون | | | | 4 | 5 | 6 | 7 | 8 | | | | | H. Recommended | Shrubs |
| 11 | Anemone species | أنيمون | | | | 4 | 5 | 6 | | | | | | | Recommended | Groundcovers |
| 12 | Phoenix dactylifera L. | نخيل البلخ | | | | 4 | | | | | | | | | Recommended | Palms |
| 13 | Paspalum vaginatum | باسالم سى شور، نخيل | | | | | 5 | 6 | 7 | 8 | 9 | 10 | | | H. Recommended | Ornamental Grasses |
| 14 | Cassia didymobotrya Syn. Senna | سنا صفراء | | | | | 5 | 6 | 7 | 8 | | | | | Recommended | Shrubs |
| 15 | Pentas lanceolata Syn. P. carnea | بنتناس | | | | | 5 | 6 | 7 | 8 | | | | | H. Recommended | Shrubs |
| 16 | Hyphaene thebaica (L.) Mart. | نخيل الدوم | | | | | 5 | 6 | | | | | | | Check | Palms |
| 17 | Acacia nilotica | أكاسيا نيلوتيكيا، السنط، شوكة مصرية، القرض | | | | | 5 | 6 | | | | | | | Recommended | Trees |
| 18 | Cassia nodosa | كاسيا ندوزاء العشرى | | | | | | 6 | 7 | 8 | 9 | 10 | | | H. Recommended | Trees |
| 19 | Portulaca grandiflora | رجلة صبار الزهور | | | | | | 6 | 7 | 8 | 9 | | | | H. Recommended | Groundcovers |
| 20 | Lawsonia inermis L. | حنة بلدى | | | | | | 6 | 7 | 8 | | | | | H. Recommended | Shrubs |
| 21 | Vitex agnus-castus L. | فاينكس أخضر | | | | | | 6 | 7 | 8 | | | | | H. Recommended | Shrubs |
| 22 | prosopis juliflora | بروسوبس، الغاف | | | | | | 6 | 7 | | | | | | Recommended | Trees |
| 23 | Alternanthera species | ألترانثيرا حمراء أو خضراء | | | | | | 6 | 7 | | | | | | Recommended | Groundcovers |
| 24 | Stephanotis floribunda | ستيڤانوتس | | | | | | | 7 | 8 | 9 | 10 | 11 | 12 | H. Recommended | Climbers |
| 25 | Cortaderia selloana | حشيشة كورتديريا | | | | | | | | 8 | 9 | | | | H. Recommended | Ornamental Grasses |
| 26 | Miscanthus sinensis Andersson | حشيشة الميكانتاس | | | | | | | | 8 | 9 | 10 | | | Recommended | Ornamental Grasses |
| 27 | Dichrostachys cinerea | ديكروستاشيس | 1 | 2 | | | | | | | 9 | 10 | 11 | 12 | H. Recommended | Shrubs |

Zone 4

Table (40) Selected species according to Blooming seasons and color scheme for zone 4, Source: Author

| No | Latin Name | Name in Arabic | Bloom شهور التزهير | | | | | | | | | | | | Selection | |
|----|---|--|--------------------|---|---|---|---|---|---|---|---|----|----|----|----------------|--------------|
| 1 | Bougainvillea Stans | جهنمية أفرنجى | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | H. Recommended | Climbers |
| 2 | Lantana camara nana | لانتانا صفراء | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | H. Recommended | Groundcovers |
| 3 | Tagetes erecta | القطيفة | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | H. Recommended | Groundcovers |
| 4 | Bauhinia variegata | خف الجمل | | 2 | 3 | 4 | | | | | | | | | Recommended | Trees |
| 5 | Pelargonium peltatum | جارونيا لير، مدادة | | | 3 | 4 | 5 | 6 | | | | 9 | 10 | 11 | H. Recommended | Groundcovers |
| 6 | Erythrina crista-galli L. | شجرة المرجان | | | | 4 | 5 | 6 | 7 | 8 | 9 | | | | H. Recommended | Trees |
| 7 | Phoenix dactylifera L. | نخيل البلخ | | | | 4 | | | | | | | | | Recommended | Palms |
| 8 | Barleria cristata | بارليريا | | | | | 5 | 6 | 7 | 8 | | | | | Recommended | Shrubs |
| 9 | Caesalpinia pulcherrima (L.) Sw. | سيزالينيا | | | | | 5 | 6 | 7 | 8 | | | | | Recommended | Shrubs |
| 10 | Carissa grandiflora | كاريسا جرانديفلورا | | | | | 5 | 6 | 7 | 8 | | | | | Check | Shrubs |
| 11 | Hibiscus rosa-sinensis | هيبسيسكس أحمر | | | | | 5 | 6 | 7 | 8 | | | | | H. Recommended | Shrubs |
| 12 | Lantana camara | لانتانا كامارا | | | | | 5 | 6 | 7 | 8 | | | | | Recommended | Shrubs |
| 13 | Lantana montevidensis | لانتانا زرقاء | | | | | 5 | 6 | 7 | 8 | | | | | Recommended | Groundcovers |
| 14 | Hyphaene thebaica | نخيل الدوم | | | | | 5 | 6 | | | | | | | Check | Palms |
| 15 | Acacia nilotica | أكاسيا نيلوتيكيا، السنط، شوكة مصرية، القرض | | | | | 5 | 6 | | | | | | | Recommended | Trees |
| 16 | Pongamia pinnata (L.) Pierre | بونجاميا | | | | | 5 | 6 | | | | | | | Check | Trees |
| 17 | Ziziphus spina-christi (L.) Desf. | النبق، السدر | | | | | 5 | 6 | | | | | | | Recommended | Trees |
| 18 | Salvia rosmarinus Spenn. | روزمارى، حصا لبان | | | | | 5 | 6 | | | | | | | Check | Shrubs |
| 19 | Cassia nodosa | كاسيا ندوزاء العشرى | | | | | | 6 | 7 | 8 | 9 | 10 | | | H. Recommended | Trees |
| 20 | Jasminum grandiflorum | ياسمين بلدى | | | | | | 6 | 7 | 8 | 9 | | | | H. Recommended | Climbers |
| 21 | Ocimum basilicum | ريحان | | | | | | 6 | 7 | 8 | | | | | Check | Shrubs |
| 22 | Hibiscus sabdariffa L. | كركدية | | | | | | 6 | 7 | | | | | | Check | Shrubs |
| 23 | Lanvandula angustifolia Syn. L. officinalis | لافندر | | | | | | | 7 | 8 | 9 | | | | Recommended | Shrubs |
| 24 | Ficus sycomorus L. | الجميز | | | | | | | 7 | 8 | | | | | H. Recommended | Trees |
| 25 | Origanum vulgare Syn. Origanum majorana | بردقوش | | | | | | | | 8 | 9 | | | | Recommended | Groundcovers |
| 26 | Euphorbia continifolia | ايڤوريا حمراء، بنت القنصل الحمراء | 1 | | | | | | | | | | | 12 | Recommended | Shrubs |
| 27 | Euphorbia pulcherrima | بنت القنصل | 1 | | | | | | | | | | | 12 | H. Recommended | Shrubs |

6.4. Environmental Impact Assessment for the park

For a precise and accurate assessment of park performance, the proposed specific designed CWP assessment Index was used to summarize the estimated performance of the park. These metrics are described in detail in the following main points and finally summarized in table (67).

As the project is still in the construction phase, the performance analysis represents an estimated analysis as the preliminary study measuring the initial analysis of air quality at the site had not been conducted until the submission of the thesis.

Sources of Data and Information

The data used for the analysis of both primary and forecasting measures were a mix of different possible sources.

Background Information

- Project design documents, reports and photos

Predictive Models and Calculators

- Project studies related to water, soil and air quality
- Online calculators and tools; iTree Eco

Secondary Data

- Publications and research studies
- Workshop with Stakeholders

Primary Data

- On-site measurements or monitoring
- Direct observation
- User surveys

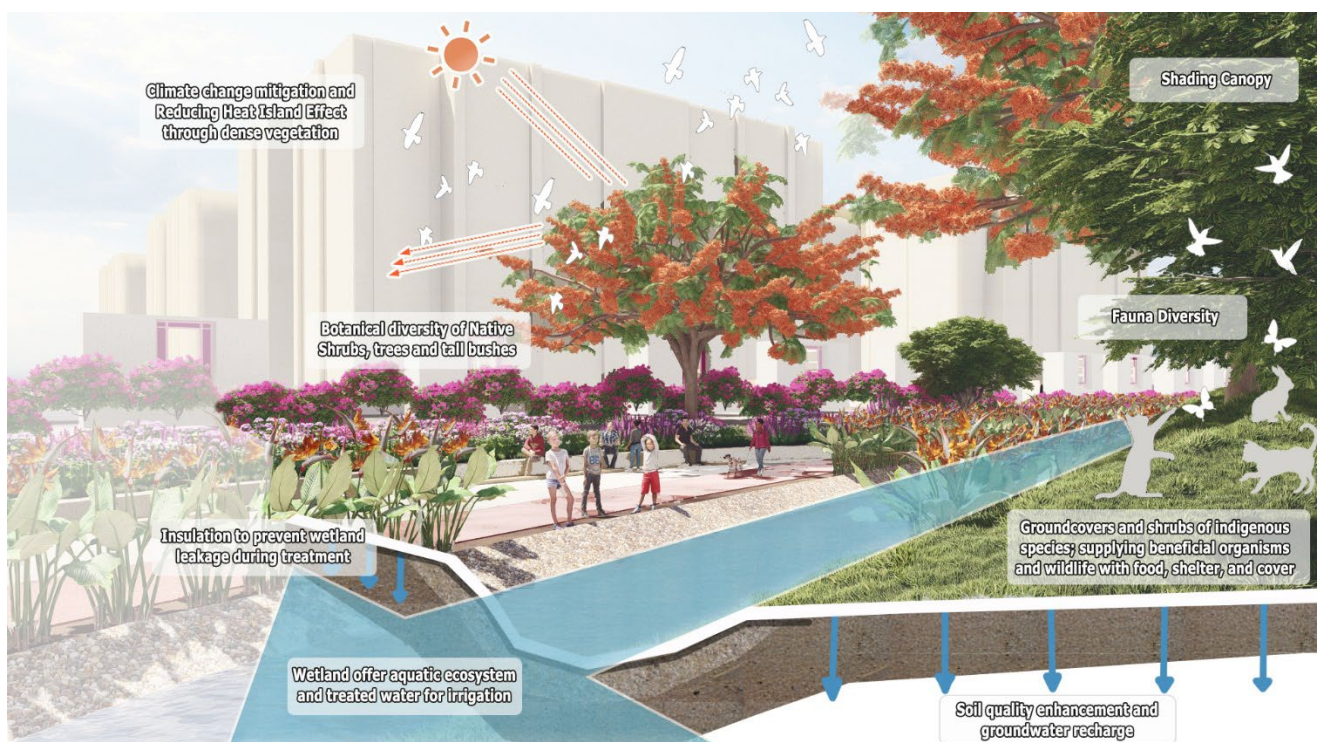
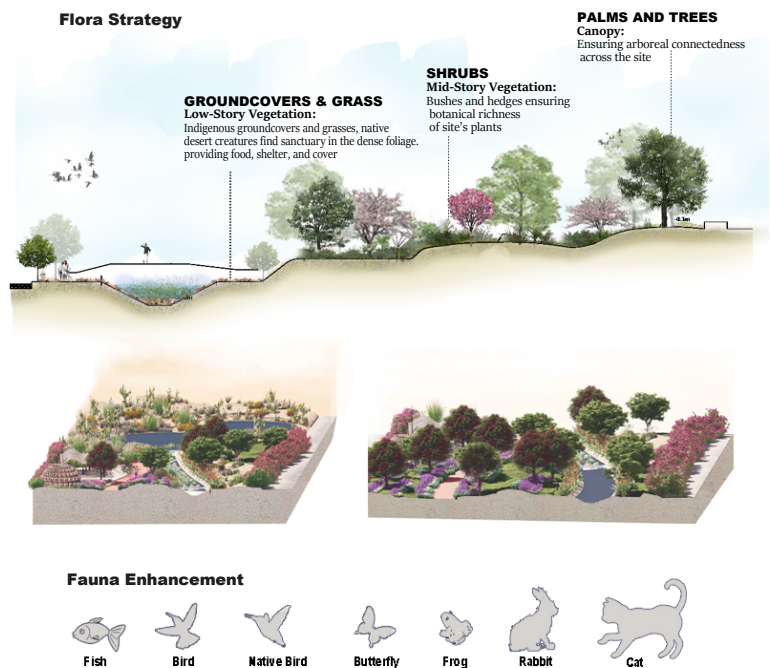


Fig. (159) Expected 10th of Ramadan Wetland Park's performance, Source: Author on rendered shots by Designers Academic team

1. Climatic Aspects

1.1. Air Quality measurements:

The air we breathe intensely impacts us.

Air Quality Index, AQI

The United States Environmental Protection Agency (EPA) created a numerical scale with color code for Air Quality Index (AQI) which is divided into several specific ranges. The index is mainly used by government agencies to communicate with the communities the pollution levels particularly in outdoor environment. The AQI inform about the pollution level as well as the imposed potential health risk to people, as the air quality we breath profoundly impacts human health as well as impacting all other creatures. (AirNow.gov, 2022)

| Daily AQI Color | Levels of Concern | Values of Index | Description of Air Quality |
|-----------------|--------------------------------|-----------------|---|
| Green | Good | 0 to 50 | Air quality is satisfactory, and air pollution poses little or no risk. |
| Yellow | Moderate | 51 to 100 | Air quality is acceptable. However, health concern for some people, particularly those who are unusually sensitive to air pollution. |
| Orange | Unhealthy for Sensitive Groups | 101 to 150 | Members of sensitive groups, young children and elderly, may experience health effects. The general public is less likely to be affected. |
| Red | Unhealthy | 151 to 200 | Most of the general public may experience health effects; sensitive groups may experience more serious health effects. |
| Purple | Very Unhealthy | 201 to 300 | Health alert: Everyone is at increased risk of health effects. |
| Maroon | Hazardous | 301 and higher | Health warning of emergency conditions: The entire population is more likely to be affected. |

Table (41) Air Quality Index (AQI), Source: AirNow.gov, 2022

Five major pollutants

The U.S. AQI is EPA's index for reporting air quality for five major air pollutants regulated by the Clean Air Act. Each of these pollutants has a national air quality standard set by EPA to protect public health: (AirNow.gov, 2022; Saad, S., et al., 2017; Great Merce, TMA, 2022)

1. Ground-level ozone
2. Particle pollution (also known as particulate matter, including PM2.5 and PM10)
3. Carbon monoxide
4. Sulfur dioxide
5. Nitrogen dioxide

| Level of Health Concern | AQI Values | O3 (ppm) | PM10 (µg/m³) | PM2.5 (µg/m³) | CO (ppm) | SO2 (ppm) | NO2 (ppm) |
|--------------------------------|------------|---------------|--------------|---------------|-------------|---------------|-------------|
| Good | 0 – 50 | 0.000 – 0.059 | 0 – 54 | 0.0 – 15.4 | 0.0 – 4.4 | 0.000 – 0.034 | – |
| Moderate | 51 – 100 | 0.060 – 0.075 | 55 – 154 | 15.5 – 40.4 | 4.5 – 9.4 | 0.035 – 0.144 | – |
| Unhealthy for Sensitive Groups | 101 – 150 | 0.076 – 0.095 | 155 – 254 | 40.5 – 65.4 | 9.5 – 12.4 | 0.145 – 0.224 | – |
| Unhealthy | 151 – 200 | 0.096 – 0.115 | 255 – 354 | 65.5 – 150.4 | 12.5 – 15.4 | 0.225 – 0.304 | – |
| Very Unhealthy | 201 – 300 | 0.116 – 0.374 | 355 – 424 | 150.5 – 250.4 | 15.5 – 30.4 | 0.305 – 0.604 | 0.65 – 1.24 |
| Hazardous | 301 – 400 | – | 425 – 504 | 250.5 – 350.4 | 30.5 – 40.4 | 0.605 – 0.804 | 1.25 – 1.64 |
| Extreme Hazardous | 401 – 500 | – | 505 – 604 | 350.5 – 500.4 | 40.5 – 50.4 | 0.805 – 1.004 | 1.65 – 2.04 |

Table (42) Air Quality Index (AQI) and pollutants' values, EPA's breakpoint, Source: Saad, S., et al., 2017 and Great Merce, TMA, 2022

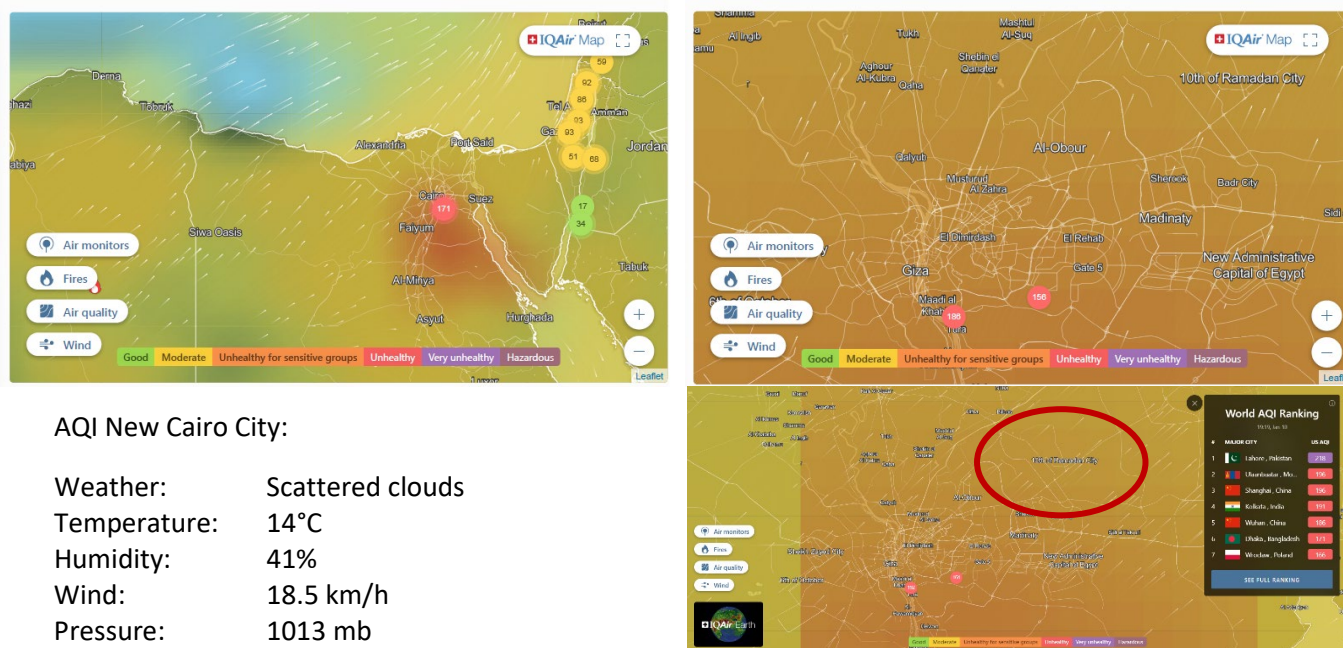
Hourly AQI index

| Air checker hourly AQI | | | PM _{2.5} Hourly µg/m ³ | PM ₁₀ Hourly µg/m ³ | NO ₂ Hourly µg/m ³ | O ₃ Hourly µg/m ³ |
|------------------------|---------------|--------|---|--|---|--|
| Good | Excellent | 91-100 | 0-10 | 0-10 | 0-10 | 0-15 |
| | Good | 81-90 | 10-15 | 10-20 | 10-20 | 15-30 |
| | Quite good | 71-80 | 15-20 | 20-30 | 20-30 | 30-40 |
| Moderate | Acceptable | 61-70 | 20-30 | 30-45 | 30-45 | 40-60 |
| | Moderate | 51-60 | 30-40 | 45-60 | 45-60 | 60-80 |
| | Insufficient | 41-50 | 40-50 | 60-75 | 60-75 | 80-100 |
| Bad | Rather poor | 31-40 | 50-70 | 75-100 | 75-100 | 100-140 |
| | Poor | 21-30 | 70-90 | 100-125 | 100-125 | 140-180 |
| | Bad | 11-20 | 90-100 | 125-150 | 125-150 | 180-200 |
| Very Bad | Very Bad | 1-10 | 100-140 | 150-200 | 150-200 | 200-240 |
| | Extremely Bad | 0 | >140 | >200 | >200 | >240 |

Table (43) Hourly Air Quality Index (AQI), Source: Airchecker, 2022

Site Air Quality Index:

According to the standards of air quality, Cairo has an unhealthy AQI on average of 171, and in the adjacent weather station for New Cairo AQI equal to 156, Cairo 152, Halwan 147, according to the measurements of Live Air quality index, AQI and PM_{2.5} air pollution in New Cairo available on IQ Air online website, measured on 10 January 2022, at 13:00, and on 19 January 2022, at 13:50. (IQ Air, 2022)



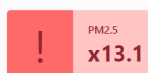
AQI New Cairo City:

Weather: Scattered clouds
 Temperature: 14°C
 Humidity: 41%
 Wind: 18.5 km/h
 Pressure: 1013 mb

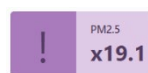
Fig. (160) Daily Air Quality Index (AQI) at site location, Source: IQ Air, 2022, on 10 January 2022

| Measurement Date | Air pollution level | Air quality index | Main pollutant |
|---------------------------|---------------------|-------------------|--|
| 10 January 2022, at 13:00 | Unhealthy | 156 US AQI | PM _{2.5} ; Concentration 65.5 µg/m ³ |
| 19 January 2022, at 13:50 | Unhealthy | 172 US AQI | PM _{2.5} ; Concentration 95.7 µg/m ³ |

Table (44) Site's Air Quality Index, Source: IQ Air, 2022, on 10 & 19 January 2022



PM_{2.5} concentration in New Cairo air measured on 10 January 2022, at 13:00 is 13.1 times above the WHO annual air quality guideline value.



PM_{2.5} concentration in New Cairo air measured on 19 January 2022, at 13:50 is 19.1 times above the WHO annual air quality guideline value

The current WHO guideline value of **10 µg/m³** (annual mean) and **25 µg/m³** (24-hour mean) was set to protect the public from the health effects of gaseous nitrogen dioxide

WHO Air quality guideline values (WHO, 2021)

| | Guideline values | Remarks |
|-------------------------------------|--|---|
| Particulate matter (PM) | Fine particulate matter (PM2.5) 5 µg/m ³ annual mean 15 µg/m ³ 24-hour mean | In addition to guideline values, the WHO Global air quality guidelines provide interim targets for concentrations of PM10 and PM2.5 aimed at promoting a gradual shift from high to lower concentrations. |
| | Coarse particulate matter (PM10) 15 µg/m ³ annual mean 45 µg/m ³ 24-hour mean | |
| Ozone (O ₃) | 100 µg/m ³ , 8-hour daily maximum* 60 µg/m ³ 8-hour mean, peak season* | * 99th percentile, (i.e. 3-4 exceedance days per year) ** Peak season is defined as an average of daily maximum 8-hour mean O ₃ concentration in the six consecutive months with the highest six-month running average O ₃ concentration |
| Nitrogen dioxide (NO ₂) | 10 µg/m ³ annual mean 25 µg/m ³ 24-hour mean | The current WHO guideline value of 10 µg/m ³ (annual mean) was set to protect the public from the health effects of gaseous nitrogen dioxide. |
| Sulfur dioxide (SO ₂) | SO ₂ 40 µg/m ³ 24-hour mean | Health effects are now known to be associated with much lower levels of SO ₂ than previously believed. A greater degree of protection is needed. |

Table (45) Air Quality guideline values, Source: WHO, 2021

Primary Analysis

A preliminary study measuring the initial analysis of air quality at the site was conducted on 19 February 2022. Unfortunately, the weather was unstable with uncommon heavy rain, which resulted in better readings than normal due to the deposition of particulate matters in air, the temperature ranged from 13°C to 16°C during the visit, the following data were collected from 3 selected points throughout the project's site.

Table (46) Site's Air Quality measures, Source: Author on 19 February 2022

| Parameter | Point 1 | Point 2 | Point 3 | Unit |
|-----------------------|---------|---------|---------|-------------------|
| O ₂ | 20.9 | 20.9 | 20.9 | % |
| O ₃ | 0.001 | 0.000 | 0.000 | PPM |
| CO | 2 | 2.5 | 1.5 | PPM |
| SO ₂ | 0.5 | 0.5 | 0.7 | PPM |
| NO ₂ | 0.03 | 0.04 | 0.04 | PPM |
| NH ₃ | 1.0 | 0.8 | 0.9 | PPM |
| CH ₄ (LEL) | 1 | 4 | 2 | PPM |
| PM _{2.5} | 30 | 28 | 31 | ug/m ³ |
| PM ₁₀ | 40 | 55 | 57 | ug/m ³ |

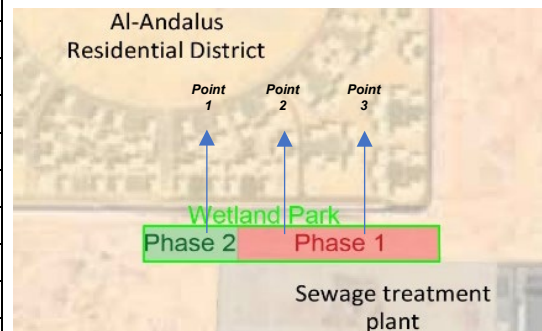


Fig. (161) Weather condition during Air Quality Measure's visit, Source: Author, Date Taken: 19 February 2022 at 10:53

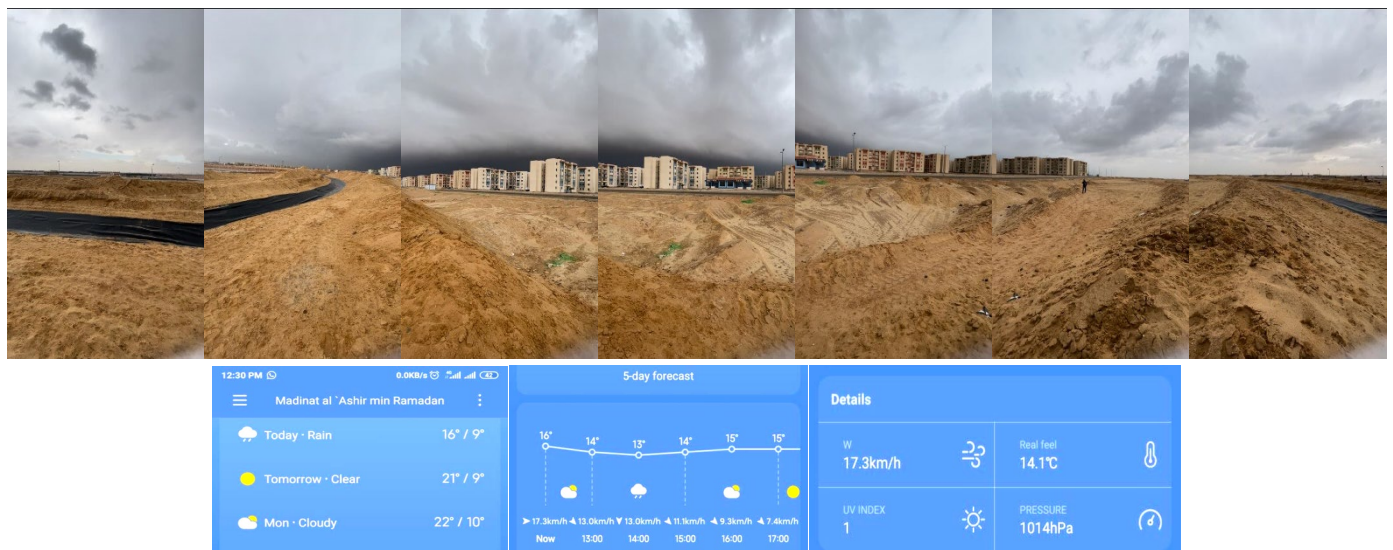




Fig. (162) Measuring and analysis of site's Air Quality, Source: Author, Date Taken: 19 February 2022 from 10:30 to 13:00
N.B.: After the occupation of the residential units, where more vehicles and human disturbance to the environment are predicted, air quality measures are expected to be more hazardous.

Performance Analysis expectation

A study was done to measure the expected analysis of air quality improvements due to increased vegetation cover. The i-Tree Eco application was used to evaluate the expected quantity of air pollutants removed by newly planted species in the Wetland Park. Pollutants removed included 109.8 g/yr of carbon monoxide (equivalent to average of 0.18 \$/yr), 2289.9 g/yr of ozone (equivalent to average of 0.24 \$/yr), 306.8 g/yr of nitrogen dioxide, 47.9 of sulfur dioxide, and 16.5 g/yr of particulate matter (equivalent to average of 1660.25 \$/yr).

The benefits calculation for newly planted trees was based on the planting plan and the tree size at installation. As the project is still in the construction phase, an actual tree surveys could not be implemented and a more accurate results could not be achieved.

Estimated results from i-Tree Eco represents minimum removal of **2770.9g of air pollutants each year** through the addition of total of 11095 vegetation, represented in 2 Palms, 137 Trees, 661 Shrubs, 15 Climbers, 6780 Groundcovers, and 3500 Ornamental Grasses. A service with an estimated value of **\$1660.67 per year**. (See Table (48) Analysis of Pollution Removal by Individual Trees for detailed analysis)

| Type | Pollution Removed (g/yr) | Removal Value (\$/yr) |
|--------------|-----------------------------|--------------------------|
| O3 | 2289.9 | 0.24 |
| CO | 109.8 | 0.18 |
| SO2 | 47.9 | N/A |
| NO2 | 306.8 | N/A |
| PM2.5 | 16.5 | 1660.25 |
| Total | 2,770.90 | 1,660.67 |

Table (47) Expected Park's Pollution Removal, Source: Author from i-Tree Eco

Pollution Removal analysis

Method: I-Tree Eco application

A study was done to measure the expected analysis of the pollution removal through the park's vegetation. Using the I-Tree application.

Limitation:

- Due to lack of data for Egypt in the i-Tree data base, the study was done on the required species in a similar climatic zone in USA. Location: Mohave Valley, Mohave, Arizona, United States of America
- Due to lack of information about some species in the i-Tree Eco application the expected measures were Not available (N/A), hence, similar species were used for estimation:
 - **Ocimum basilicum** to Phlomis fruticose,
 - **Catharanthus roseus** to Tabernaemontana orientalis,
 - **Origanum vulgare** to Cuphea hyssopifolia
 - **Paspalum vaginatum** to Nolina Michaux (Beargrass)

Table (48) Analysis of Pollution Removal by Individual Trees, Source: Author from i-Tree Eco

| Tree ID | Type | Genus | Species | Pollution Removed (g/yr) | | | | | Removal Value (\$/yr) | | | | |
|---------|--------------------|---------------|--------------|--------------------------|---------------|--------------|-------------|-------------|-----------------------|-------------|----------|----------|--------------|
| | | | | CO | O3 | NO2 | SO2 | PM2.5 | CO | O3 | NO2 | SO2 | PM2.5 |
| Pd | Palms | Phoenix | dactylifera | 3.2 | 66.5 | 8.9 | 1.4 | 0.5 | 0.01 | 0.01 | 0 | 0 | 0 |
| Al | Trees | Azadirachta | indica | 25.3 | 517 | 69.5 | 10.8 | 3.8 | 0.04 | 0.05 | 0 | 0 | -0.01 |
| Cag | Trees | Cassia | glauc | 11.6 | 237.1 | 31.9 | 5 | 1.7 | 0.02 | 0.03 | 0 | 0 | 0 |
| Dr | Trees | Delonix | regia | 12.4 | 253.8 | 34.1 | 5.3 | 1.8 | 0.02 | 0.03 | 0 | 0 | 0 |
| Jo | Trees | Jacaranda | mimosifolia | 30.8 | 629.3 | 84.6 | 13.2 | 4.6 | 0.05 | 0.07 | 0 | 0 | -0.01 |
| Spc | Trees | Spathodea | campanulata | 25.5 | 521.3 | 70.1 | 10.9 | 3.8 | 0.04 | 0.06 | 0 | 0 | -0.01 |
| Cg | Shrubs | Carissa | grandiflora | 0.5 | 10.3 | 1.4 | 0.2 | 0.1 | 0 | 0 | 0 | 0 | 0 |
| Cea | Shrubs | Cestrum | aurantiacum | 0.2 | 5 | 0.7 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cof | Shrubs | Cordyline | fruticosa | 0.1 | 2.4 | 0.3 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dp | Shrubs | Duranta | plumieri | 0.1 | 3 | 0.4 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Js | Shrubs | Jasminum | sambac | 0.3 | 6.4 | 0.9 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lo | Shrubs | Lavandula | angustifolia | 0.1 | 3.1 | 0.4 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pz | Shrubs | Pelargonium | zonal | 0.2 | 4.3 | 0.6 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ob | Shrubs | Ocimum | basilicum | 0.1 | 2.6 | 0.3 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sr | Shrubs | Strelitzia | reginae | 0.2 | 4.9 | 0.7 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bs | Climbers | Bougainvillea | stans | 0.3 | 6.6 | 0.9 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Catr | round-covers | Catharanthus | roseus | 0.5 | 10.8 | 1.4 | 0.2 | 0.1 | 0 | 0 | 0 | 0 | 0 |
| Lac | round-covers | Lantana | camara nana | 0.3 | 6.7 | 0.9 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ov | round-covers | Origanum | vulgare | 0.2 | 4.7 | 0.6 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pp | round-covers | Pelargonium | peltatum | 0.2 | 3.7 | 0.5 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pv | Ornamental Grasses | Paspalum | vaginatum | 0.1 | 1.4 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Total | | 112.4 | 2300.9 | 309.4 | 48.2 | 16.7 | 0.18 | 0.25 | 0 | 0 | -0.03 |

- Pollution removal value is calculated based on the prices of
 - o \$1.63 per kilogram (CO),
 - o \$0.11 per kilogram (O3),
 - o \$0.01 per kilogram (NO2),
 - o \$0.00 per kilogram (SO2),
 - o \$-1.86 per kilogram (PM2.5).
- A value of zero may indicate that ancillary data (pollution, weather, energy, etc.) is not available for this location or that the reported amounts are too small to be shown.
- In 2021, trees in Constructed Wetland Park 10th Ramadan emitted an estimated 517.6 grams of volatile organic compounds (VOCs) (200.7 grams of isoprene and 317 grams of monoterpenes). Emissions vary among species based on species characteristics

Summary

- Pollution Removal: 2.787 kilograms/year (\$0.4/year)
- Carbon Storage: 2.955 metric tons (\$556)
- Carbon Sequestration: 111.5 kilograms (\$21/year)
- Oxygen Production: 297.3 kilograms/year
- Avoided Runoff: 1.225 cubic meters/year (\$2.89/year)

1.2. Urban Micro-Climate:

Primary Analysis

A primary study was done to measure the primary analysis of the Urban Micro-climate in the location. The following data were collected.

Table (49) Site's Air Temperature measures, Source: Author on 19 February 2022

| Parameter | Point 1 | Point 2 | Point 3 | Unit |
|--------------------------|---------|---------|---------|--------|
| Temperature | 15.8 | 15.5 | 16.1 | °C |
| Relative Humidity | 64.1 | 60.2 | 62.1 | %RH |
| Sound Level | 51 | 60 | 57 | dB (A) |

Performance Analysis expectation

A study was done to measure the expected analysis of the Urban Micro-Climate in the location. Measuring the expected reduction percentage in Heat Island Effect due to increased vegetation cover and water bodies. Reducing localized temperatures and heat island impacts is one of the most important expected outcomes of the park. Due to the absence of any plantation in the site before the construction of the park and the direct sunlight and solar radiation impact, solar reflectance index (SRI), on the sand ground. Expected reduction in the average ground-level temperature of the park due to the plantation of 137 shading trees, as the tree canopy cover at least 50% of the site. To determine the cooling effect of the tree canopy, the air temperature of the park is expected to be at least 5-10°C lower when compared to the air temperature of the primary analysis, where the location had no vegetative cover or water bodies.

Nevertheless, the vegetative cover and the use of the red aggregates as ground cover for the pathways allows for more Urban Heat Island mitigation; which includes heat storage capacity, emissivity, thermal conductivity, albedo (*the fraction of solar radiation reflected by a surface or object, (Hulley, M., 2012), a high albedo tend to contribute to the reduction of urban heat island to a great extent*). The vegetative cover and gravel surfaces can significantly cool down more rapidly at night-time than the asphalt and sand surfaces. (*Common concrete and asphalt pavements have an albedo of 0.05 to 0.40, which indicates that they are absorbing 95% to 60% of the reached solar energy instead of reflecting it away*). Due to their permeability, they also help to discharge water back into the ground. The vegetative cover has the impact of "air-conditioning effect". According to the US Environmental Protection Agency (EPA), trees help reducing surface and air temperatures through evapotranspiration, and by providing shades. Shading helps decrease the surface temperature, which might be 11–25°C lower than peak temperatures of similar unshaded surfaces. Evapotranspiration, on its own or through combination with shading, could assist in the reduction of the peak summer temperatures by 1–5°C. They can lower the temperature by 5-10°C if planted close together. (US EPA, 2021)

| Material | Albedo |
|------------------------|--------------------|
| Grass | 0.25 – 0.30 |
| Brick and stone | 0.20 – 0.40 |
| Desert Sand | 0.20 - 0.40 |
| Trees | 0.15 – 0.18 |
| Tar | 0.08 – 0.20 |
| Asphalt | 0.05 – 0.20 |

Table (50): Albedo for various materials, Source: US EPA, 1992

Temperature improvements:

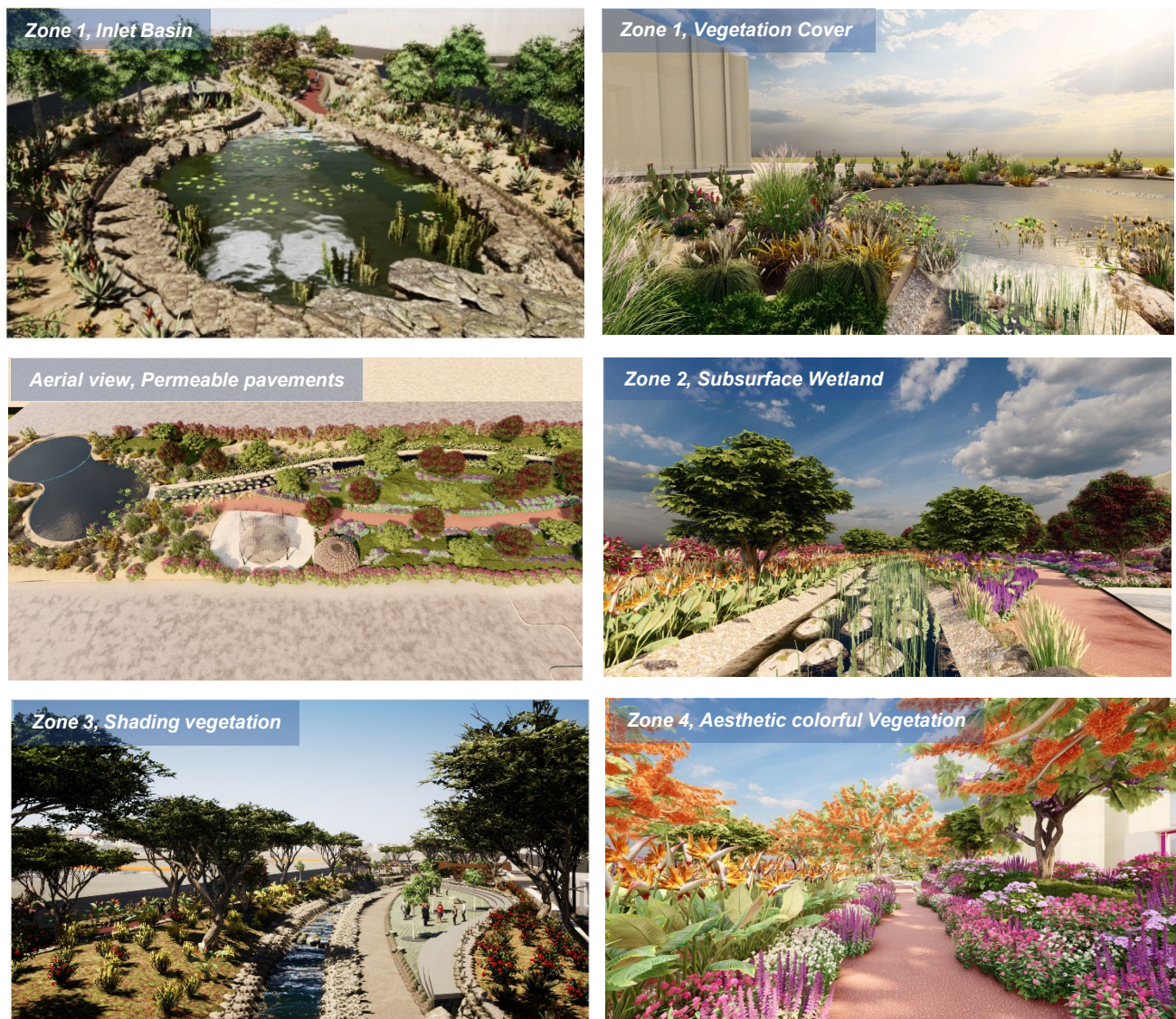
According to researchers at Lawrence Berkeley National Laboratory (LBNL), Studies estimated the following (Pomerantz, M., et al., 2000; Taha, H., 1996; Taha, H., 1997):

- Decrease of surface temperature by **4°C** for every 10 % increase in solar reflectance
- Reduction in air temperature by **0.6°C** for every increase from 10 – 35 % of pavement reflectance
- Increasing worldwide pavement albedo, on an average of 35 to 39 %, contribute to reduction in global carbon dioxide (CO₂) emissions equivalent to \$400 billion
- Permeable pavements evaporate water and contribute to lower air temperature

Other benefits that are achieved due to reducing air temperatures (Wong, E. et al., 2012):

- Permeable pavements allow rainwater infiltration into the ground, decreasing stormwater runoff, boosting soil wetness, and improving water quality through filtration of dust, dirt, and pollutants
- Lower air temperature result in significant reduced energy use.
- Low energy use contributes to lower air pollution, greenhouse gas emissions and increase air quality.
- Cooler air temperatures will decelerate the rate of ground-level ozone development
- Improving quality of life, by providing aesthetic value, habitat for many species, and can reduce noise.

Fig. (163) Park's proposed renderings, Source: Designers Academic team



1.3. Carbon Footprint

Primary Analysis

A preliminary study measuring the initial analysis of Carbon Footprint at the site had not been conducted as the site is currently with no vegetation.

Performance Analysis expectation

An estimated study was executed to measure the expected analysis of the Capturing, storing, or preventing the release of carbon into the atmosphere in the location. The i-Tree Eco application was used to evaluate the expected quantity of Carbon Storage and Carbon Sequestration as a result of the newly planted species in the Wetland Park. Due to unavailability of information of the calculation coefficients relevant to Egypt and to some species' survival rate and annual sequestration coefficients in the i-Tree Eco application, the study was implemented on comparative location with similar climate zone and some species of similar physical characteristics and growth pattern to the unavailable species.

Method 1: I-Tree Eco calculations:

Through sequestering carbon in newly growth, trees help reducing the amount of carbon in the atmosphere every year. The amount of annual carbon sequestered is improved according to the size and health of the trees. The overall sequestration of Constructed Wetland Park 10th Ramadan trees is about 13.96 metric tons of carbon per year with an associated value of \$2.62 thousand.

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases much of the stored carbon back into the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Table (51) Carbon Sequestration and Storage of Individual Trees, Source: Author from i-Tree Eco

| Tree ID | Type | Genus | Species | Carbon Storage of Individual Trees | | Carbon Sequestration of Individual Trees | |
|---------|--------------------|---------------|--------------|------------------------------------|------------|--|------------|
| | | | | Carbon Storage (kg) | % of Total | Gross Carbon Sequestration (kg/yr) | % of Total |
| Pd | Palms | Phoenix | dactylifera | 175.8 | 6 | 0.2 | 0.1 |
| Al | Trees | Azadirachta | indica | 1216 | 41.1 | 1.5 | 1.3 |
| Cag | Trees | Cassia | glauc | 270.1 | 9.1 | 19.8 | 17.7 |
| Dr | Trees | Delonix | regia | 479 | 16.2 | 27.9 | 25 |
| Jo | Trees | Jacaranda | mimosifolia | 525.7 | 17.8 | 27.6 | 24.7 |
| Spc | Trees | Spathodea | campanulata | 248.3 | 8.4 | 12.4 | 11.1 |
| Cg | Shrubs | Carissa | grandiflora | 7.8 | 0.3 | 2.9 | 2.6 |
| Cea | Shrubs | Cestrum | aurantiacum | 1 | 0 | 1 | 0.9 |
| Cof | Shrubs | Cordyline | fruticosa | 0.6 | 0 | 0.6 | 0.5 |
| Dp | Shrubs | Duranta | plumieri | 1.1 | 0 | 1.2 | 1.1 |
| Js | Shrubs | Jasminum | sambac | 0.9 | 0 | 1.1 | 1 |
| Lo | Shrubs | Lavandula | angustifolia | 1.4 | 0 | 1.2 | 1.1 |
| Pz | Shrubs | Pelargonium | zonal | 1 | 0 | 1 | 0.9 |
| Ob | Shrubs | Ocimum | basilicum | 8 | 0.3 | 3.1 | 2.8 |
| Sr | Shrubs | Strelitzia | reginae | 0.6 | 0 | 0.6 | 0.5 |
| Bs | Climbers | Bougainvillea | stans | 1.2 | 0 | 1 | 0.9 |
| Catr | Ground-cover | Catharanthus | roseus | 1.1 | 0 | 1 | 0.9 |
| Lac | Ground-cover | Lantana | camara nana | 7.7 | 0.3 | 3.1 | 2.8 |
| Ov | Ground-cover | Origanum | vulgare | 0.9 | 0 | 1.5 | 1.3 |
| Pp | Ground-cover | Pelargonium | peltatum | 6.6 | 0.2 | 2.8 | 2.5 |
| Pv | Ornamental Grasses | Paspalum | vaginatum | 0.2 | 0 | 0.1 | 0.1 |
| Total | | | | 2955.2 | 100% | 111.6 | 100% |

- Carbon storage and gross carbon sequestration value is calculated based on the price of \$0.18800/Kg

Trees in Constructed Wetland Park 10th Ramadan are estimated to store 98.8 metric tons of carbon (\$18.6 thousand). Of the species sampled, *Azadirachta indica* stores the most carbon (approximately 43.1% of the total carbon stored) and *Lantana camara* sequesters the most (approximately 31.2% of all sequestered carbon.)

Carbon storage minimum of **105.8 kg each year** and Carbon Sequestration minimum of **23945 kg** is expected through the addition of total of 11095 vegetation, represented in 2 Palms, 137 Trees, 661 Shrubs, 15 Climbers, 6780 Groundcovers, and 3500 Ornamental Grasses. An estimated value of **\$20** and **\$554 per year** respectively. (See Table (57) Benefits and Costs Summary of Individual Trees for detailed analysis)

| Type | Amount (kg) | Value (\$) |
|--|-------------|------------|
| Carbon Storage | 105.8 | 20 |
| Gross Carbon Sequestration (per year) | 23945 | 554 |

Table (52) Expected Park's total Carbon Sequestration and Storage, Source: Author from i-Tree Eco

Method 2: U.S. Department of Energy's Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings

Another estimated study was implemented using another method based on the U.S. Department of Energy's 1998, *Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings*. This method calculates carbon sequestration through the multiplication of coefficients related to the plantation number of vegetation, age, size, growth rate and their expected annual sequestration rate for each species. (Age estimated as 10 years for Palms, 5 years for trees and 2 years for other species) (Temesgen, F. et al., 2020)

Carbon Sequestration minimum of **18310.24 kg each year** through total 11095 vegetation, represented in 2 Palms, 137 Trees, 661 Shrubs, 15 Climbers, 6780 Groundcovers, and 3500 Ornamental Grasses. An estimated value of **\$424 per year**. (See Table (53) Carbon sequestration modeling assumptions)

| Type | Amount (kg) | Value (\$) |
|--|-------------|------------|
| Gross Carbon Sequestration (per year) | 18310.24 | 424 |

Table (53). Carbon sequestration modeling assumptions, Source: Author from i-Tree Eco

| Tree ID | A. Species Characteristics | | | B. Tree Age | C. Number of Trees Planted | D. Survival Factor | E. Number of Surviving Trees (C x D) | F. Annual Sequestration Rate (lbs./tree) | G. Carbon Sequestration (lbs.) (E x F) | I. Carbon Sequestration (Kg) (G x 0.453592) |
|---|----------------------------|-------------------|-----------------------|-------------|----------------------------|--------------------|--------------------------------------|--|--|---|
| | Name | Tree Type (H / C) | Growth Rate (S, M, F) | | | | | | | |
| Pd | Phoenix dactylifera | H | F | 10 | 2 | 0.589 | 1.178 | 19.3 | 22.7354 | 10.31259556 |
| Ai | Azadirachta indica | H | F | 5 | 35 | 0.658 | 23.03 | 10.1 | 232.603 | 105.50686 |
| Cag | Cassia glauca | C | F | 5 | 35 | 0.658 | 23.03 | 6.4 | 147.392 | 66.85583206 |
| Dr | Delonix regia | H | F | 5 | 30 | 0.658 | 19.74 | 10.1 | 199.374 | 90.43445141 |
| Jo | Jacaranda mimosifolia | H | S | 5 | 12 | 0.658 | 7.896 | 3.2 | 25.2672 | 11.46099978 |
| Spc | Spathodea campanulata | H | M | 5 | 25 | 0.658 | 16.45 | 6.1 | 100.345 | 45.51568924 |
| Cg | Carissa grandiflora | H | M | 2 | 16 | 0.736 | 11.776 | 3.5 | 41.216 | 18.69524787 |
| Cea | Cestrum aurantiacum | H | F | 2 | 80 | 0.736 | 58.88 | 5.4 | 317.952 | 144.2204836 |
| Cof | Cordyline fruticosa | H | M | 2 | 30 | 0.736 | 22.08 | 3.5 | 77.28 | 35.05358976 |
| Dp | Duranta plumieri | H | F | 2 | 95 | 0.736 | 69.92 | 5.4 | 377.568 | 171.2618243 |
| Js | Jasminum sambac | H | S | 2 | 80 | 0.736 | 58.88 | 2 | 117.76 | 53.41499392 |
| Lo | Lanvandula angustifolia | H | F | 2 | 50 | 0.736 | 36.8 | 5.4 | 198.72 | 90.13780224 |
| Pz | Pelargonium zonal | H | F | 2 | 100 | 0.736 | 73.6 | 5.4 | 397.44 | 180.2756045 |
| Ob | Ocimum basilicum | C | F | 2 | 110 | 0.736 | 80.96 | 3.1 | 250.976 | 113.8407058 |
| Sr | Strelitzia reginae | C | M | 2 | 100 | 0.736 | 73.6 | 2 | 147.2 | 66.7687424 |
| Bs | Bougainvillea Stans | H | F | 2 | 15 | 0.736 | 11.04 | 5.4 | 59.616 | 27.04134067 |
| Catr | Catharanthus roseus | H | F | 2 | 4000 | 0.736 | 2944 | 5.4 | 15897.6 | 7211.024179 |
| Lac | Lantana camara nana | H | F | 2 | 1400 | 0.736 | 1030.4 | 5.4 | 5564.16 | 2523.858463 |
| Ov | Origanum vulgare | C | M | 2 | 1280 | 0.736 | 942.08 | 2 | 1884.16 | 854.6399027 |
| Pp | Pelargonium peltatum | H | F | 2 | 100 | 0.736 | 73.6 | 5.4 | 397.44 | 180.2756045 |
| Pv | Paspalum vaginatum | H | F | 2 | 3500 | 0.736 | 2576 | 5.4 | 13910.4 | 6309.646157 |
| Total Pounds of Carbon Sequestered | | | | | | | | | 40367.2046 | 18310.24107 |
| Total Pounds of Equivalent CO2 Sequestered X 3.67 | | | | | | | | | 148147.6409 | 67198.58472 |
| Equivalent CO2 Sequestered in Short Tons /2000 | | | | | | | | | 74.07382044 | 33.59929236 |

- **Tree type:** Hardwood (H)/ Conifer (C) - **Growth Rate:** Slow (S), Moderate (M), Fast (F)

- A mature tree absorbs carbon dioxide at a rate of 48 pounds per year
- Carbon storage and sequestration, carbon values are multiplied by \$78.5 per ton of carbon (range = \$17.2-128.7 tC⁻¹) based on the estimated social costs of carbon for 2010 with a 3% discount rate (Interagency Working Group, 2010)

2. Sustainability

2.1. Energy

Primary Analysis

The site is currently a desertic area with no buildings, vegetation or any other features, there is no energy use in the site location.

Performance Analysis expectation

Alternative purification cost

An estimation of the energy saving in the treatment process through biological wastewater treatment process of constructed wetland in comparison to the conventional wastewater treatment plants was studied. Intensive energy is required for mechanical components, in the conventional wastewater treatment systems, with high operational and investment costs, while energy requirement for constructed wetland is very low or zero energy input, thus, operation and maintenance costs are much lower leading to a great energy saving.

Biogas

As a mechanism of benefiting from the Vegetation used in the biological treatment of wastewater, the vegetation collected from the drain after the end of the treatment period can be reused in many activities, such as generating biogas for use as green energy in the electricity for the park. The benefits and advantages can be summarized in the following points (AbouElElla, S., 2017)

- Waste disposal of water weeds and converting them into clean energy production
- Biogas gas is non-toxic, clean and has no combustion exhaust and can be used directly in lighting, running irrigation machines and generating electricity
- Biogas fertilizer is produced in the form of a water suspension that is used directly with irrigation water or dried and packed in bags to be used in scattered form
- Protecting the environment from pollution caused by the presence of water weeds in the watercourse
- Maintaining public health
- Reducing pollution by not using liquefied petroleum gas
- Good fertilizers due to production of small amount of solid waste produced by the biogas fermenter

Solar Energy

In another approach for energy saving, the team suggested a design for the implementation of 200 solar cells is to be used across the park for the efficient utilization of the solar energy in this arid city. Those solar plants to be installed over light poles across the park, which are lit using energy produced to reduce annual energy consumption for park lighting. Furthermore, these poles use LED bulbs which have an extended lifespan, at least four times more than that of standard outdoor lighting, with less frequent replacement, and hence reduction in maintenance and off-site storage costs. Due to the low-budget available, this Solar Energy plan was postponed to later phase of park upgrading.

Measuring sensors

Measurement sensors for energy consumption and irrigation are also planned to be used across the park at the light poles and in the water path, for continuous measuring and assessment of the park's performance and for efficient utilization of park's benefits and management of the energy and water consumption.

2.2. Materials

Primary Analysis

According to the site visit, the site does not have any materials, except for the sand, gravel and stones. For the improvement of soil quality to be suitable for plantation, it is required to use composites in the planned areas that will be planted.

Performance Analysis expectation

Vegetation composite

According to the vegetation consultant, it is required to use composite with the soil to be suitable for vegetation as follows: 15-20 Kg/ tree and 10-15 Kg/ shrub

Soil Reuse

Excavation of the water path is reused as backfilling for the construction of the hill and the different levels inside the garden. In addition to the regional sourcing of soil, plants, and constructing materials

Hardscape

The park uses natural stone and local material, the hardscape is designed of various types of natural materials, which is cost efficient, offer permeability and ensure efficient use of available materials on site to achieve sustainability. The main use of the red aggregates as ground cover for the pathways allows for more Urban Heat Island mitigation as previously discussed, which includes several urban micro climatic benefits, (See 1.2 Urban Micro-Climate section), some of the important benefits of the used permeable natural hardscape are:

- Permeable pavements evaporate water and contribute to lower air temperature
- Permeable pavements allow rainwater infiltration into the ground
- Lower air temperature result in significant reduced energy use
- Low energy use contributes to lower air pollution, greenhouse gas emissions and increase air quality
- Cooler air temperatures will decelerate the rate of ground-level ozone development

Vegetation waste management

Waste management could be implemented through the previously mentioned Biogas plants, as they are an efficient way for the reuse of available materials, represented in the collected vegetation from the drain after the end of the treatment period, to produce green energy through generating biogas to be used in the electricity for the park. (See 2.1 Energy)

Insulation

The water path is carefully insulated using the best insulation sheets available to ensure that no leakage of contaminated water occurs in the path into the groundwater.

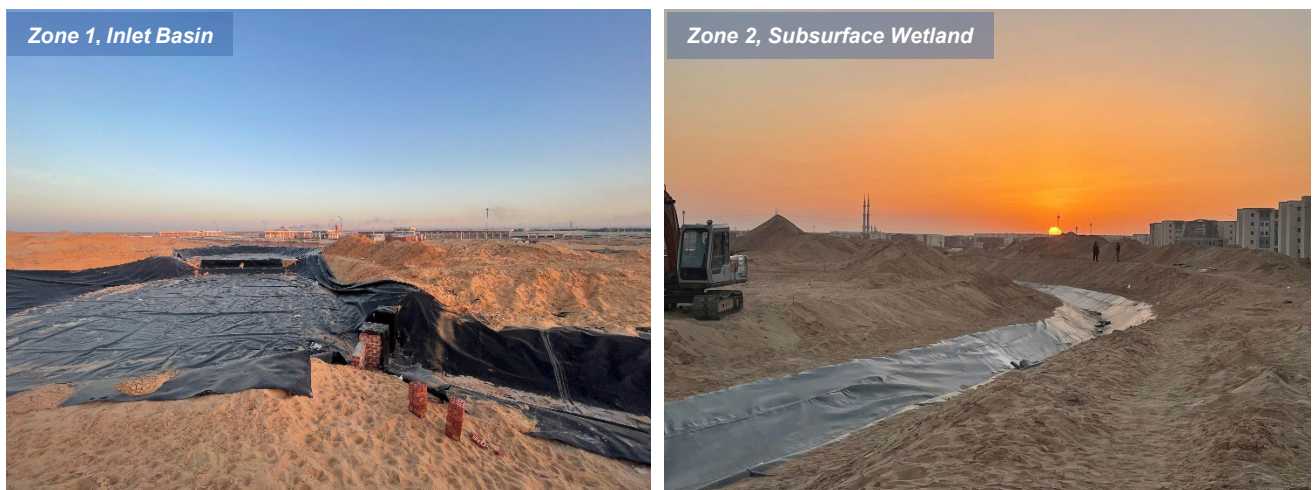


Fig. (164): Insulation of the water pathway at Park, Source: Author, Date Taken: November 27, 2021, at 16:40

2.3. Solid/ Liquid Wastes

Primary Analysis

A primary study was done to measure the primary analysis of the solid/liquid wastes in the location. Since the location is a desertic area with no buildings or vegetation, no solid/liquid wastes were observed. While the water inflow from the sewage treatment plant adjacent to the site, could be considered as liquid wastes that is planned to be recycled.

Performance Analysis expectation

Liquid Wastes Reuse:

The water inflow from the sewage treatment plant adjacent to the site considered as liquid wastes that is recycled for reuse after purification in the wetland waterway. Estimated amount is ranging from minimum of **200 to 400** m3 per day.

Organic Wastes Reuse

The aquatic plants in the water pathway requires regular cultivation and disposal. Which could be reused through the application of a small Biogas plant that contribute to the production of methane that could be reused as an alternative energy source for efficient use of energy and reduction in energy costs of the park. (See 2.1 Energy)

As mentioned before, an experimental study is ongoing for the reuse of these organic wastes through biogas small plant, which will produce methane that could be used in the park as energy substitute for electricity in the park's utilities. No accurate data about the average expected production or the equivalent reduction in energy costs is available yet.

2.4. Soil

Primary Analysis

A primary study was done to measure the primary analysis of the soil in the location. The following data were collected:

Preliminary measurements:

- **SOIL:**

The results of the chemical analysis of the soil samples: (Source: Designers Academic team's 2nd & 3rd report)

Grade

| | |
|------|-----------------------------------|
| 1.06 | EC (dSm-1) (1.5) |
| 2.0 | CaCO3% |
| 7.3 | CEC (Meq1100g) |
| 0.14 | OM (%) |
| 0.45 | Iron Proportion (ppm) |
| 0.17 | (ppm) The proportion of copper |
| 0.87 | (ppm) The proportion of zinc |
| 0.30 | (ppm) The percentage of manganese |

According to the soil results, it is required to use 15-20 Kg composite per tree and 10-15 Kg/ shrub to be suitable for vegetation

Performance Analysis expectation

A study was done to measure the expected analysis of the soil fertility and upgrading due to the plantation of 11095 vegetation in the location. As a result of the introduction of the various species in the desertic location, a serious improvement in the soil and its fertility is expected. Some species helps control erosion in sandy areas like *Paspalum vaginatum*. Other species helps improves soil quality where they succeed in sandy soil like *Jacaranda mimosifolia*, *Cestrum aurantiacum*, *Jasminum sambac*, *Ocimum basilicum*, *Bougainvillea Stans*, *Lantana camara nana*. Some groundcover species are used in slopes to help as soil stabilizer like *Catharanthus roseus*, *Lantana camara nana*, *Origanum vulgare*, *Pelargonium peltatum* and *Paspalum vaginatum*

Reference for soil analysis, (Friedman, D. et al., 2001)

3. Biodiversity

3.1 Flora

Primary Analysis

From site visits no specific flora species was observed in the project's site due to non-existing of any green spaces or water bodies. According to the water quality simulation report done by the mechatronic and Hydrology team of the project the following vegetation list was recommended for the water quality that would be achieved after treatment in the wetland.

Table (54) Ornamental plants suggested according to the water quality

Source: Designers Academic team's 2nd report

| N | scientific name | Arabic name | Type | Water (liter/day) | Blooming season |
|----|------------------------------------|----------------------------|-------------------------|---------------------|---|
| 1 | <i>Cassia nodosa</i> | كاسيا نودوزا | Semi deciduous tree | 60-80 | Pink in summer and autumn |
| 2 | <i>Peltophorum africanum</i> | بيلتوفورم | Evergreen tree | 60-80 | yellow in summer and autumn |
| 3 | <i>Ailanthus altissima</i> | شجرة السماء | Deciduous tree | 40-50 | greenish-white in spring |
| 4 | <i>Ceratonia Siligua</i> | الخروب | Evergreen tree | 40-50 | red or tend to red in autumn |
| 5 | <i>Acacia farnesiana</i> | الفنتنة | Deciduous tree | 40-50 | Orange-yellow in spring (fragrant smell) |
| 6 | <i>Koelreuteria paniculata</i> | كولروتريرا | Evergreen tree | 50-60 | Blossoms are yellow in (autumn) they turn red |
| 7 | <i>Citharexylum quadrangular</i> | السندروس | Deciduous tree | 50-60 | Vegetable trees (worthless flowers) |
| 8 | <i>Spathodea campanulata</i> | اسباثوديا | Evergreen tree | 60-80 | Red in winter |
| 9 | <i>Khaya senegalensis</i> | الكايا- الماهوجني الأفريقي | Deciduous tree | 60-80 | Yellow flowers in summer |
| 10 | <i>Bauhinia sp</i> | خف الجمل | Deciduous tree | 50-60 | Pink, white, and purple flowers in spring |
| 11 | <i>Bombax malabaricum</i> | البومباكس | Deciduous tree | 60-80 | Red in winter and spring |
| 12 | <i>Delonix regia</i> | البوانسيانا | Deciduous tree | 60-80 | Red in summer |
| 13 | <i>Erthrina variegata</i> | إرثرينا | Deciduous tree | 60-80 | Red in winter and spring |
| 14 | <i>Ficus laurifolia</i> | فيكس مانجو | Evergreen tree | 60-80 | Vegetable trees (worthless flowers) |
| 15 | <i>Morus sp</i> | التوت | Deciduous tree | 50-60 | Vegetable trees (worthless flowers) |
| 16 | <i>Tecoma stans</i> | التيكوما الصفراء | Evergreen tree | 50-60 | Yellow in spring, summer, and fall |
| 17 | <i>Thevitea peruviana</i> | ثيفيتيا | Evergreen tree | 50-60 | Yellow- orange in summer, and fall |
| 18 | <i>Paulownia tomentosa</i> | بولونيا | Deciduous tree | 60-80 | White in winter and spring |
| 19 | <i>Pongamia pinnata</i> | بونجاميا | Deciduous tree | 50-60 | Reddish white in spring |
| 20 | <i>Moringa oleifera</i> | المورينجا | Deciduous tree | 50-60 | White - creamy in May with an aromatic scent |
| 21 | <i>Albizia julibrissin</i> | كاليبرا | Deciduous tree | 35-40 | Pink in spring and summer |
| 22 | <i>Pittosporum tobira</i> | البيتسبورم | Evergreen shrub | 25-30 | White/yellow aromatic scent flowers in winter/spring |
| 23 | <i>Murraya paniculata</i> | موريا | Evergreen shrub | 25-30 | White or cream in spring, aromatic |
| 24 | <i>Plumeria alba</i> | البياسمين الهندي | Deciduous shrub | 30-40 | Yellowish white in summer |
| 25 | <i>Ervatamia coronaria</i> | تابرنا | Evergreen shrub | 25-30 | White blossoms in spring, summer / autumn - aromatic |
| 26 | <i>Acalypha wilkesiana</i> | أكاليفا | Evergreen shrub | 25-30 | used for leaf beauty (valueless flowers) |
| 27 | <i>Hibiscus rosa-sinensis</i> | هيبسكس | Evergreen shrub | 25-30 | Red almost the whole year |
| 28 | <i>Lagerstroemia indica</i> | تمر حنة | Evergreen shrub | 25-30 | Pink, red or white in summer |
| 29 | <i>Tecomaria capensis</i> | تيكوماريا حمراء | Evergreen shrub | 25-30 | Red all year long |
| 30 | <i>Russelia equisetiformis</i> | روسيليا | Evergreen shrub | 25-30 | Red in winter and spring |
| 31 | <i>integerrimalatropa</i> | جاثروفا | Evergreen shrub | 25-30 | Flowers in red clusters almost all year long |
| 31 | <i>Leucophyllum frutescens</i> | ليكوفيلم | Evergreen shrub | 25-30 | Violet/ purple/ pink. June through late summer / early fall |
| 32 | <i>Phoenix dactylifera</i> | نخيل البلح | Palm tree | 60-80 | ---- |
| 33 | <i>Washingtonia sp</i> | برتشارديا | Ornamental tree | 60-80 | ---- |
| 34 | <i>Plumbago auriculata</i> | البلمباجو | Climber/Evergreen shrub | 25-30 | Sky blue flowers in clusters almost all year long |
| 35 | <i>Clerodendron splendens</i> | كليرا | Evergreen Climber | 25-30 | Red flowers in clusters in winter and spring |
| 36 | <i>Ipomea palmata</i> | ست الحسن | Evergreen Climber | 15-20 | Bell's flowers are purple almost all year long |
| 37 | <i>Thenbergia grandiflora</i> | ثمبرجيا | Evergreen Climber | 15-20 | Cyan blossoms all year long |
| 38 | <i>Crinum asiaticum</i> | كرينم ابيض | Summer bulbs | 5-15 liter/ m2/ day | Big white trumpet flowers scented in summer |
| 39 | <i>Hemerocallis aurantica</i> | الهيميروكالس | Summer bulbs | 5-15 liter/ m2/ day | Orange blossoms in summer and autumn |
| 40 | <i>Canna indica</i> | الكانا (السنبل) | Summer bulbs | 5-15 liter/ m2/ day | Flowers of different colors throughout the year |
| 41 | <i>Aptenia cordifolia</i> | ابتينيا زاحف | Ground cover | 5-15 liter/ m2/ day | Flowers are red in spring, summer, and fall |
| 42 | <i>Portulacaria grandiflora</i> | رجلة الزهور | Ground cover | 5-15 liter/ m2/ day | many colors flowers |
| 43 | <i>Lantana montevidensis</i> | لانтана مدادة | Ground cover | 5-15 liter/ m2/ day | Blue blossoms in summer |
| 44 | <i>Duranta erecta "Gold Mound"</i> | دورانتا ليموني | Edging plants | 5-15 liter/ m2/ day | Blue flowers in spring and summer |
| 45 | <i>Rosemarinus officinalis</i> | حصى لبنان | Edging plants | 5-15 liter/ m2/ day | lusters of pale blue to white flowers in winter and spring |
| 46 | <i>Senecio cineraria</i> | زناريا | Ground cover | 5-15 liter/ m2/ day | Yellow flowers |
| 47 | <i>Sansevieria hyacinthoides</i> | جلد النمر الأخضر | Succulent plant | 5-15 liter/ m2/ day | ----- |
| 48 | <i>Sansevieria trifasciata</i> | جلد النمر الأصفر | Succulent plant | 5-15 liter/ m2/ day | ----- |
| 49 | <i>Yucca filamentosa</i> | يوكا ابره ادم | Succulent plant | 5-15 liter/ m2/ day | ----- |
| 50 | <i>Peniocereus striatus</i> | الشمعدان | Succulent plant | 5-15 liter/ m2/ day | ----- |
| 51 | <i>Euphorbia tirucalli</i> | اللبنية | Succulent plant | 5-15 liter/ m2/ day | ----- |
| 52 | <i>Euphorbia splendens</i> | إيفوريا دم المسيح | Succulent plant | 5-15 liter/ m2/ day | ----- |
| 53 | <i>Euphorbia nerifolia</i> | إيفوريا الجوافة | Succulent plant | 5-15 liter/ m2/ day | ----- |
| 54 | <i>Alpinia nutans</i> | البيينيا | semi aquatic plant | 5-10 | ----- |
| 55 | <i>Pennisetum sp</i> | بنيسيتم | aquatic plant | 5-15 | ----- |
| 56 | <i>Paspalum vaginatum</i> | بسيالم | turfgrass | 5-15 liter/ m2/ day | ----- |

Performance Analysis expectation

According to the developed Park design by the project's design team, an area of 7830 m of plantation is designed from the total park area. The following table shows the flora species introduced to the site according to the landscape design by the landscape team, where the selection was done from the previously analyzed flora selection guidance (See tables: 26 to 40). Some other exotic species were also selected due to the low budget of the project and for other aesthetic purposes. These species are affordable and are commonly used in landscape projects in Egypt.

Data from total of 11095 vegetation, represented in 2 Palms, 137 Trees, 661 Shrubs, 15 Climbers, 6780 Groundcovers, and 3500 Ornamental Grasses planted throughout Constructed Wetland Park 10th Ramadan were analyzed using the i-Tree Eco model.

Vegetation quantity and Species specifications

Table (55) Species specs and quantities of each species, Source: Author

| Latin Name | Name in Arabic | Abb | Bloom شهور التزهير | | | | | | | | | | | | Flower Color لون الزهرة | Form تكوين النبات | Aroma رائحة | Growth Rate معدل النمو | Water احتياج للمياه | Sun شمس | Salinity تحمل الملوحة | Drought تحمل الجفاف | Wind تحمل الرياح | Quantity |
|---|-----------------------|------|--------------------|---|---|---|---|---|---|---|---|----|----|----|--|-------------------|---------------|------------------------|---------------------|---------------|--------------------------|---------------------|------------------|----------|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | | | | | | | | | | |
| PALMS | | | | | | | | | | | | | | | | | | | | | | | | |
| Phoenix dactylifera | نخيل الباح | Pd | | | | 4 | | | | | | | | | Creamy | Evergreen | No Aroma | Fast | Moderate | Full Sun | Tolerant 800-1200 ppm | Tolerant | High Resistant | 2 |
| TREES | | | | | | | | | | | | | | | | | | | | | | | | |
| Azadirachta indica | النيم | Ai | | | 3 | 4 | | | | | | | | | White | Deciduous | Flower / Seed | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi | 35 |
| Cassia glauca | كاسيا جلوكا، صفار | Cag | | | | | 5 | 6 | 7 | 8 | 9 | | | | Bright yellow | Evergreen | No Aroma | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | M. Tolerance | High Resistant | 35 |
| Delonix regia | بوانسيانا | Dr | | | | 4 | 5 | 6 | 7 | 8 | | | | | Red | Deciduous | No Aroma | Fast | Moderate | Full Sun | Tolerant 800-1200 ppm | Tolerant | Semi Resistant | 30 |
| Jacaranda mimosifolia Syn. J.ovalifolia | جكارندا | Jo | | | 3 | 4 | 5 | | | | | | | | Purple-blue | Deciduous | No Aroma | Slow | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi Resistant | 12 |
| Spathodea campanulata | اسباوديا | Spc | | | | | | 6 | 7 | | | 10 | 11 | | Yellow-rimmed - Scarlet-red | Deciduous | Flower | Moderate | Moderate | Full Sun | Intolerant | Tolerant | Semi | 25 |
| SHRUBS | | | | | | | | | | | | | | | | | | | | | | | | |
| Carissa grandiflora | كاريسا جرانديفلورا | Cg | | | | | 5 | 6 | 7 | 8 | | | | | White | Evergreen | Flower | Moderate | Low | Full Sun | M. Tolerance 600-800 ppm | H. Tolerance | High Resistant | 16 |
| Cestrum aurantiacum Syn. C. chaculanum | مسك الليل | Cea | | | | | | 6 | 7 | 8 | | | | | Bright Yellow to Orange | Evergreen | Flower | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi Resistant | 80 |
| Cordyline fruticosa | كوردلين | Cof | | | | | | | | 7 | 8 | | | | Red-green foliage White purple | Evergreen | No Aroma | Moderate | Moderate | Partial Shade | Intolerant | Intolerant | Semi | 30 |
| Duranta plumieri Syn. D. repens | دورانتا خضراء / ليونى | Dp | | | | | | | | 7 | 8 | 9 | | | Blue | Evergreen | No Aroma | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | 95 |
| Jasminum sambac | الفل | Js | | | | 4 | 5 | 6 | 7 | 8 | 9 | | | | Snow-white | Evergreen | Flower | Slow | Moderate | Full Sun | Intolerant | Intolerant | Semi Resistant | 80 |
| Lanvandula angustifolia Syn. L. officinalis | لافندر | Lo | | | | | | | | 7 | 8 | 9 | | | Lilac-blue | Evergreen | Flower / Leaf | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | Semi Resistant | 50 |
| Ocimum basilicum | ريحان | Ob | | | | | | 6 | 7 | 8 | | | | | Purple - White | Evergreen | Flower / Leaf | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | M. Tolerance | Semi Resistant | 110 |
| Pelargonium zonal | جارونيا | Pz | | | 3 | 4 | 5 | 6 | 7 | | | | | | Scarlet - Purple, Pink - White - Orange - Yellow | Evergreen | Flower / Leaf | Fast | Moderate | Partial Shade | Intolerant | Intolerant | Semi | 100 |
| Strelitzia reginae | عصفور الجنة | Sr | | | | | | 5 | 6 | 7 | 8 | | | | Orange- yellow | Evergreen | No Aroma | Moderate | Moderate | Full Sun | Intolerant | Tolerant | High | 100 |
| CLIMBERS | | | | | | | | | | | | | | | | | | | | | | | | |
| Bougainvillea Stans | جهنمية | Bs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Yellow-Orange-Pink -Red-White- Purple | Evergreen | No Aroma | Fast | Moderate | Full Sun | Tolerant 800-1200 ppm | Tolerant | High Resistant | 15 |
| GROUNDCOVERS | | | | | | | | | | | | | | | | | | | | | | | | |
| Catharanthus roseus | وينكا | Catr | | | | | 4 | 5 | 6 | 7 | 8 | | | | White - Pink – Red - Orange | Evergreen | No Aroma | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High | 4000 |
| Lantana camara nana | لانطانا صفراء | Lac | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Bright Yellow | Evergreen | Flower / Leaf | Fast | Moderate | Full Sun | M. Tolerance 600-800 ppm | L. Tolerance | High Resistant | 1400 |
| Origanum vulgare Syn. O. majorana | بردقوش | Ov | | | | | | | | | 8 | 9 | | | White - Pink - Pale Lilac | Evergreen | Flower / Leaf | Moderate | Moderate | Full Sun | M. Tolerance 600-800 ppm | Tolerant | High Resistant | 1280 |
| Pelargonium peltatum | جارونيا لير، مدادة | Pp | | | 3 | 4 | 5 | 6 | | | | 9 | 10 | 11 | Pink - Scarlet - White with dark-streaked petals | Evergreen | Flower / Leaf | Fast | Moderate | Partial Shade | M. Tolerance 600-800 ppm | Intolerant | Semi Resistant | 100 |
| ORNAMENTAL GRASSES | | | | | | | | | | | | | | | | | | | | | | | | |
| Paspalum vaginatum | باسيالم سى شدة، نجلا | Pv | | | | | 5 | 6 | 7 | 8 | 9 | 10 | | | Brown | Evergreen | No Aroma | Fast | Moderate | Full Sun | Tolerant 800-1200 ppm | Intolerant | High Resistant | 3500 |

Vegetation According to Blooming Seasons

Table (56) Species according to blooming months and designed color schemes,
Source: Author

| Latin Name | Name in Arabic | Bloom شهور التزهير | | | | | | | | | | | | Flower Color لون الزهرة | Type |
|---|-----------------------|--------------------|---|---|---|---|---|---|---|---|----|----|----|--|--------------------|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | | |
| Bougainvillea Stans | جهنمية أفرنجى | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Yellow - Orange - Pink – Red - White or Purple | Climbers |
| Lantana camara nana | لاتناتا صفراء | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Bright Yellow | Groundcovers |
| Phoenix dactylifera | نخيل الباج | | | | 4 | | | | | | | | | Creamy | Palms |
| Azadirachta indica | النيم | | | 3 | 4 | | | | | | | | | White | Trees |
| Jacaranda mimosifolia Syn. J. ovalifolia | جكارندا | | | 3 | 4 | 5 | | | | | | | | Purple-blue | Trees |
| Pelargonium zonal | جارونيا | | | 3 | 4 | 5 | 6 | 7 | | | | | | Scarlet - Purple, Pink - White - Orange - Yellow | Shrubs |
| Pelargonium peltatum | جارونيا لير، مدادة | | | 3 | 4 | 5 | 6 | | | 9 | 10 | 11 | | Pink - Scarlet - White with dark-streaked petals | Groundcovers |
| Delonix regia | بوانسيانا | | | | 4 | 5 | 6 | 7 | 8 | | | | | Red | Trees |
| Catharanthus roseus | وينكا | | | | 4 | 5 | 6 | 7 | 8 | | | | | White - Pink - Red - Orange | Groundcovers |
| Jasminum sambac | الفل | | | | 4 | 5 | 6 | 7 | 8 | 9 | | | | Snow-white | Shrubs |
| Carissa grandiflora | كاريسا جرانديفلورا | | | | | 5 | 6 | 7 | 8 | | | | | White | Shrubs |
| Strelitzia reginae | عصفور الجنة | | | | | 5 | 6 | 7 | 8 | | | | | Orange- yellow | Shrubs |
| Cassia glauca | كاسيا جلوكا، صفار | | | | | 5 | 6 | 7 | 8 | 9 | | | | Bright yellow | Trees |
| Paspalum vaginatum | باسيالم سى شور، نجيل | | | | | 5 | 6 | 7 | 8 | 9 | 10 | | | Brown | Ornamental Grasses |
| Cestrum aurantiacum Syn. C. chaculanum | مسك الليل | | | | | | 6 | 7 | 8 | | | | | Bright Yellow to Orange | Shrubs |
| Ocimum basilicum | ريحان | | | | | | 6 | 7 | 8 | | | | | Purple - White | Shrubs |
| Spathodea campanulata | اسيالوديا | | | | | | 6 | 7 | | | 10 | 11 | | Yellow-rimmed - Scarlet-red | Trees |
| Cordyline fruticosa | كوردلين | | | | | | | 7 | 8 | | | | | Red-green foliage White purple | Shrubs |
| Duranta plumieri Syn. D. repens | دورانتا خضراء، ليمونى | | | | | | | 7 | 8 | 9 | | | | Blue | Shrubs |
| Lanvandula angustifolia Syn. L. officinalis | لافندر | | | | | | | 7 | 8 | 9 | | | | Lilac-blue | Shrubs |
| Origanum vulgare Syn. O. majorana | بردقوش | | | | | | | | 8 | 9 | | | | White - Pink - Pale Lilac | Groundcovers |

Method: I-Tree Eco application

A study was done to measure the expected analysis of the flora in the site, due to the introduction of different flora species and the aquatic species in the waterway. The following data were expected for the following points:

- Benefits and Costs Summary
- Composition and Structure
- Pollution Removal
- VOC Emissions
- Hydrology Effects

Limitation:

- Due to lack of data for Egypt in the i-Tree data base, the study was done on the required species in a similar climatic zone in USA. Location: Mohave Valley, Mohave, Arizona, United States of America
- Due to lack of information about some species in the i-Tree Eco application the expected measures were Not available (N/A), hence, similar species were used for estimation:
 - **Ocimum basilicum** to Phlomis fruticose,
 - **Catharanthus roseus** to Tabernaemontana orientalis,
 - **Origanum vulgare** to Cuphea hyssopifolia
 - **Paspalum vaginatum** to Nolina Michaux (Beargrass)

i-Tree Analysis summary:

An assessment of the vegetation structure, function, and value of the Constructed Wetland Park 10th Ramadan urban forest was conducted during 2021. Data from total of 11095 vegetation, represented in 2 Palms, 137 Trees, 661 Shrubs, 15 Climbers, 6780 Groundcovers, and 3500 Ornamental Grasses planted throughout Constructed Wetland Park 10th Ramadan were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station:

- Pollution Removal: 166.6 kilograms/year (\$24/year)
- Carbon Storage: 98.77 metric tons (\$18.6 thousand)
- Carbon Sequestration: 13.96 metric tons (\$2.62 thousand/year)
- Oxygen Production: 37.23 metric tons/year
- Avoided Runoff: 82.96 cubic meters/year (\$196/year)
- Building energy savings: N/A – data not collected
- Avoided carbon emissions: N/A – data not collected
- Replacement values: \$3.24 million

1- Benefits and Costs Summary

Table (57) Benefits and Costs Summary of Individual Trees, Source: Author from i-Tree Eco

| Tree ID | Type | Genus | Species | No. of Trees | DBH | Replacement Value of individual tree | Oxygen Production of individual tree | Carbon Storage of Individual Trees | | Carbon Sequestration of Individual Trees | | Avoided Runoff | | Pollution Removal | | Total Annual Benefits |
|---------|--------------------|---------------|--------------|--------------|-----|--------------------------------------|--------------------------------------|------------------------------------|--------|--|---------|----------------------|---------|-------------------|---------|-----------------------|
| | | | | | | | | (kg) | (\$) | (kg/yr) | (\$/yr) | (m ³ /yr) | (\$/yr) | (g/yr) | (\$/yr) | |
| Pd | Palms | Phoenix | dactylifera | 2 | 50 | 1,270.05 | 0.40 | 175.8 | 33.06 | 0.2 | 0.03 | 0.11 | 0.27 | 161 | 0.03 | 96.77 |
| Al | Trees | Azadirachta | indica | 35 | 50 | 5,679.65 | 4.00 | 1,216.00 | 228.61 | 1.5 | 0.28 | 15.56 | 36.74 | 21924 | 4.5 | 13164.67 |
| Cag | Trees | Cassia | glauc | 35 | 30 | 2,288.45 | 52.70 | 270.1 | 50.77 | 19.8 | 3.72 | 7.14 | 16.85 | 10052 | 2.07 | 6161.65 |
| Dr | Trees | Delonix | regia | 30 | 38 | 3,441.46 | 74.40 | 479 | 90.06 | 27.9 | 5.24 | 6.55 | 15.46 | 9225 | 1.9 | 5691.19 |
| Jo | Trees | Jacaranda | mimosifolia | 12 | 50 | 5,679.65 | 73.50 | 525.7 | 98.83 | 27.6 | 5.18 | 6.5 | 15.33 | 9148.8 | 1.88 | 5550.86 |
| Spc | Trees | Spathodea | campanulata | 25 | 50 | 5,679.65 | 33.00 | 248.3 | 46.68 | 12.4 | 2.33 | 11.21 | 26.46 | 15790 | 3.24 | 9532.33 |
| Cg | Shrubs | Carissa | grandiflora | 16 | 5.4 | 88.1 | 7.6 | 7.8 | 1.47 | 2.9 | 0.54 | 0.14 | 0.34 | 200 | 0.04 | 128.32 |
| Cea | Shrubs | Cestrum | aurantiacum | 80 | 2 | 41.06 | 2.7 | 1 | 0.19 | 1 | 0.19 | 0.34 | 0.81 | 480 | 0.1 | 305.63 |
| Cof | Shrubs | Cordyline | fruticosa | 30 | 2 | 630.33 | 1.6 | 0.6 | 0.11 | 0.6 | 0.11 | 0.06 | 0.15 | 90 | 0.02 | 57.92 |
| Dp | Shrubs | Duranta | plumieri | 95 | 2 | 41.06 | 3.3 | 1.1 | 0.2 | 1.2 | 0.23 | 0.25 | 0.58 | 342 | 0.07 | 227.05 |
| Js | Shrubs | Jasminum | sambac | 80 | 2 | 41.06 | 2.9 | 0.9 | 0.18 | 1.1 | 0.21 | 0.44 | 1.04 | 624 | 0.13 | 390.38 |
| Lo | Shrubs | Lavandula | angustifolia | 50 | 2 | 41.06 | 3.3 | 1.4 | 0.26 | 1.2 | 0.23 | 0.13 | 0.31 | 185 | 0.04 | 121.5 |
| Pz | Shrubs | Pelargonium | zonal | 100 | 2 | 41.06 | 2.7 | 1 | 0.19 | 1 | 0.19 | 0.37 | 0.87 | 520 | 0.11 | 332 |
| Ob | Shrubs | Ocimum | basilicum | 110 | 5 | 75.53 | 8.3 | 8 | 1.51 | 3.1 | 0.5 | 0.63 | 1.5 | 891 | 0.18 | 590.7 |
| Sr | Shrubs | Strelitzia | reginae | 100 | 2 | 630.33 | 1.6 | 0.6 | 0.11 | 0.6 | 0.11 | 0.22 | 0.52 | 310 | 0.06 | 195 |
| Bs | Climbers | Bougainvillea | stans | 15 | 2 | 41.06 | 2.7 | 1.2 | 0.23 | 1 | 0.19 | 0.06 | 0.15 | 90 | 0.02 | 56.85 |
| Catr | Ground-covers | Catharanthus | roseus | 4000 | 2 | 41.06 | 2.7 | 1.1 | 0.21 | 1 | 0.19 | 16.07 | 37.92 | 22800 | 4.65 | 14480 |
| Lac | Ground-covers | Lantana | camara nana | 1400 | 5 | 75.53 | 8.3 | 7.7 | 1.45 | 3.1 | 0.59 | 7.89 | 18.63 | 11060 | 2.28 | 7434 |
| Ov | Ground-covers | Origanum | vulgare | 1280 | 2 | 41.06 | 3.9 | 0.9 | 0.17 | 1.5 | 0.28 | 4.13 | 9.74 | 5760 | 1.19 | 3814.4 |
| Pp | Ground-covers | Pelargonium | peltatum | 100 | 5 | 75.53 | 7.4 | 6.6 | 1.25 | 2.8 | 0.52 | 0.92 | 2.18 | 1310 | 0.27 | 839 |
| Pv | Ornamental Grasses | Paspalum | vaginatum | 3500 | 0.5 | 630.33 | 0.2 | 0.2 | 0.04 | 0.1 | 0.01 | 4.23 | 9.98 | 5950 | 1.22 | 3605 |
| | | Total | | 11,095 | | 26,573 | 297 | 2,955 | 556 | 112 | 21 | 83 | 196 | 116,913 | 24 | 72,775 |

- Carbon storage and gross carbon sequestration value is calculated based on the price of \$0.18800 per kilogram.
- Avoided runoff value is calculated by the price \$2.361/m³.
- Energy saving value is calculated based on the prices of \$127.80 per MWH and \$16.35 per MBTU.
- Pollution removal value is calculated based on the prices of
 - o \$1.63 per kilogram (CO),
 - o \$0.11 per kilogram (O3),
 - o \$0.01 per kilogram (NO2),
 - o \$0.00 per kilogram (SO2),
 - o \$-1.86 per kilogram (PM2.5).
- Replacement value is the estimated local cost of having to replace a tree with a similar tree.
- A value of zero may indicate that ancillary data (pollution, weather, energy, etc.) is not available for this location or that the reported amounts are too small to be shown.

2- Composition and Structure

Composition and Structure for both individual species and total expected

Table (58) Composition and Structure for individual species, Source: Author from i-Tree Eco

| Tree ID | Type | Genus | Species | Per Tree | | | | | | | | | | | |
|---------|--------------------|---------------|--------------|------------------|---------|------------|-------------------|------|----------------|------|-----------------|-------------------|------|-----------------|------|
| | | | | Importance Value | Avg DBH | Avg Height | Canopy Cover (m²) | | Leaf Area (m²) | | Leaf Area Index | Leaf Biomass (kg) | | Basal Area (m²) | |
| | | | | | (cm) | (m) | Value | % | Value | % | | Value | % | Value | % |
| Jo | Trees | Jacaranda | mimosifolia | 32.1 | 50 | 16.9 | 74 | 16.5 | 486.9 | 27.4 | 6.6 | 29.6 | 18 | 0.2 | 20 |
| Spc | Trees | Spathodea | campanulata | 27.4 | 50 | 16.9 | 76.9 | 17.1 | 403.3 | 22.7 | 5.2 | 24.6 | 14.9 | 0.2 | 20 |
| Ai | Trees | Azadirachta | indica | 27.2 | 50 | 20.6 | 94.2 | 21.0 | 400 | 22.5 | 4.2 | 29 | 17.6 | 0.2 | 20 |
| Dr | Trees | Delonix | regia | 15.8 | 38 | 17.2 | 62.5 | 13.9 | 196.3 | 11 | 3.1 | 17 | 10.3 | 0.1 | 11.6 |
| Cag | Trees | Cassia | glauca | 15.1 | 30 | 15 | 47.1 | 10.5 | 183.4 | 10.3 | 3.9 | 47.6 | 29 | 0.1 | 7.2 |
| Pd | Palms | Phoenix | dactylifera | 7.7 | 50 | 6.9 | 35.5 | 7.9 | 51.4 | 2.9 | 1.4 | 8.6 | 5.2 | 0.2 | 20 |
| Cg | Shrubs | Carissa | grandiflora | 5.2 | 5.4 | 4.4 | 6 | 1.3 | 8 | 0.4 | 1.3 | 1.2 | 0.7 | <0.1 | 0.2 |
| Lac | Groundcovers | Lantana | camara nana | 5 | 5 | 4.7 | 3.7 | 0.8 | 5.1 | 0.3 | 1.4 | 0.7 | 0.4 | <0.1 | 0.2 |
| Js | Shrubs | Jasminum | sambac | 5 | 2 | 4.2 | 4 | 0.9 | 5 | 0.3 | 1.2 | 0.4 | 0.2 | <0.1 | <0.1 |
| Pp | Groundcovers | Pelargonium | peltatum | 4.8 | 5 | 5.2 | 5.35 | 1.25 | 5.8 | 0.35 | 1.2 | 0.45 | 0.3 | <0.1 | 0.1 |
| Js | Shrubs | Pelargonium | zonal | 4.8 | 2 | 4 | 5.35 | 1.25 | 5.8 | 0.35 | 0.9 | 0.45 | 0.3 | <0.1 | 0.1 |
| Bs | Climbers | Bougainvillea | stans | 4.8 | 2 | 4 | 3.9 | 0.9 | 3.8 | 0.2 | 1 | 0.6 | 0.4 | <0.1 | <0.1 |
| Cea | Shrubs | Cestrum | aurantiacum | 4.8 | 2 | 3.7 | 3.5 | 0.8 | 3.8 | 0.2 | 1.1 | 0.3 | 0.2 | <0.1 | <0.1 |
| Cof | Shrubs | Cordyline | fruticosa | 4.8 | 2 | 4 | 3.9 | 0.9 | 1.9 | 0.1 | 0.5 | 0.3 | 0.2 | <0.1 | <0.1 |
| Ov | Groundcovers | Origanum | vulgare | 4.8 | 5 | 0.4 | 3.9 | 0.9 | 2.9 | 0.2 | 0.7 | 0.4 | 0.2 | <0.1 | <0.1 |
| Dp | Shrubs | Duranta | plumieri | 4.8 | 2 | 3.7 | 2 | 0.4 | 2.3 | 0.1 | 1.1 | 0.3 | 0.2 | <0.1 | <0.1 |
| Lo | Shrubs | Lavandula | angustifolia | 4.8 | 2 | 3.7 | 2 | 0.4 | 2.4 | 0.1 | 1.2 | 0.6 | 0.4 | <0.1 | <0.1 |
| Pv | Ornamental Grasses | Paspalum | vaginatum | 4.8 | 0.5 | 0.1 | 3.5 | 0.8 | 1.1 | 0.1 | 0.3 | 0.2 | 0.1 | <0.1 | <0.1 |
| Ob | Shrubs | Ocimum | basilicum | 4.8 | 2 | 0.9 | 3.7 | 0.8 | 5.2 | 0.3 | 1.4 | 1.4 | 0.8 | <0.1 | 0.2 |
| Sr | Shrubs | Strelitzia | reginae | 4.8 | 2 | 4 | 4.2 | 0.9 | 2 | 0.1 | 0.5 | 0.3 | 0.2 | <0.1 | <0.1 |
| Catr | Groundcovers | Catharanthus | roseus | 4.8 | 2 | 1 | 3.8 | 0.8 | 3.6 | 0.2 | 1 | 0.5 | 0.3 | <0.1 | <0.1 |
| Total | | | | | | | 449 | 100 | 1,780 | 100 | | 164.5 | 100 | 1 | 100 |

Table (59) Expected total Composition and Structure according to species, Source: Author from i-Tree Eco

| Tree ID | Type | Genus | Species | Total Planted species | | | | | | | | |
|---------|--------------------|---------------|--------------|-----------------------|------|---------|-------------------|---------|----------------|--------|-------------------|-------|
| | | | | Tree Count | | Avg DBH | Canopy Cover (m²) | | Leaf Area (m²) | | Leaf Biomass (kg) | |
| | | | | Value | % | (cm) | Value | % | Value | % | Value | % |
| Jo | Trees | Jacaranda | mimosifolia | 12 | 0.1 | 888 | 1.9 | 5842.8 | 9.9 | 355.2 | 4.5 | 12 |
| Spc | Trees | Spathodea | campanulata | 25 | 0.2 | 1922.5 | 4.0 | 10082.5 | 17.2 | 615 | 7.9 | 25 |
| Ai | Trees | Azadirachta | indica | 35 | 0.3 | 3297 | 6.9 | 14000 | 23.8 | 1015 | 13.0 | 35 |
| Dr | Trees | Delonix | regia | 30 | 0.3 | 1875 | 3.9 | 5889 | 10.0 | 510 | 6.5 | 30 |
| Cag | Trees | Cassia | glauca | 35 | 0.3 | 1648.5 | 3.5 | 6419 | 10.9 | 1666 | 21.3 | 35 |
| Pd | Palms | Phoenix | dactylifera | 2 | 0.0 | 71 | 0.1 | 102.8 | 0.2 | 17.2 | 0.2 | 2 |
| Cg | Shrubs | Carissa | grandiflora | 16 | 0.1 | 96 | 0.2 | 128 | 0.2 | 19.2 | 0.2 | 16 |
| Lac | Groundcovers | Lantana | camara nana | 1400 | 12.7 | 5180 | 10.9 | 7140 | 12.2 | 980 | 12.5 | 1400 |
| Js | Shrubs | Jasminum | sambac | 80 | 0.7 | 320 | 0.7 | 400 | 0.7 | 32 | 0.4 | 80 |
| Pp | Groundcovers | Pelargonium | peltatum | 100 | 0.9 | 535 | 1.1 | 580 | 1.0 | 45 | 0.6 | 100 |
| Js | Shrubs | Pelargonium | zonal | 100 | 0.9 | 535 | 1.1 | 580 | 1.0 | 45 | 0.6 | 100 |
| Bs | Climbers | Bougainvillea | stans | 15 | 0.1 | 58.5 | 0.1 | 57 | 0.1 | 9 | 0.1 | 15 |
| Cea | Shrubs | Cestrum | aurantiacum | 80 | 0.7 | 280 | 0.6 | 304 | 0.5 | 24 | 0.3 | 80 |
| Cof | Shrubs | Cordyline | fruticosa | 30 | 0.3 | 117 | 0.2 | 57 | 0.1 | 9 | 0.1 | 30 |
| Ov | Groundcover | Origanum | vulgare | 1280 | 11.6 | 4992 | 10.5 | 3712 | 6.3 | 512 | 6.5 | 1280 |
| Dp | Shrubs | Duranta | plumieri | 95 | 0.9 | 190 | 0.4 | 218.5 | 0.4 | 28.5 | 0.4 | 95 |
| Lo | Shrubs | Lavandula | angustifolia | 50 | 0.5 | 100 | 0.2 | 120 | 0.2 | 30 | 0.4 | 50 |
| Pv | Ornamental Grasses | Paspalum | vaginatum | 3500 | 31.7 | 12250 | 25.8 | 3850 | 6.6 | 700 | 8.9 | 3500 |
| Ob | Shrubs | Ocimum | basilicum | 110 | 1.0 | 407 | 0.9 | 572 | 1.0 | 154 | 2.0 | 110 |
| Sr | Shrubs | Strelitzia | reginae | 100 | 0.9 | 420 | 0.9 | 200 | 0.3 | 30 | 0.4 | 100 |
| Catr | Groundcovers | Catharanthus | roseus | 4000 | 36.2 | 15200 | 32 | 14400 | 24.5 | 2000 | 25.6 | 4000 |
| | | Total | | 11058 | 100 | 47572 | 100 | 58729.3 | 100 | 7825.9 | 100 | 11058 |

3- VOC Emissions

Table (60) VOC Emissions by Individual Trees, Source: Author from i-Tree Eco

| Tree ID | Type | Genus | Species | VOC Emissions by Individual Trees | | |
|---------|--------------------|---------------|--------------|-----------------------------------|-------------|--------------|
| | | | | Isoprene | Monoterpene | VOCs |
| | | | | (g/yr) | (g/yr) | (g/yr) |
| Pd | Palms | Phoenix | dactylifera | 142.8 | 0 | 142.8 |
| Al | Trees | Azadirachta | indica | 6.4 | 27.1 | 33.5 |
| Cag | Trees | Cassia | glauc | 0 | 140.7 | 140.7 |
| Dr | Trees | Delonix | regia | 0 | 30.7 | 30.7 |
| Jo | Trees | Jacaranda | mimosifolia | 0 | 0 | 0 |
| Spc | Trees | Spathodea | campanulata | 14.9 | 17.2 | 32.1 |
| Cg | Shrubs | Carissa | grandiflora | 0 | 0 | 0 |
| Cea | Shrubs | Cestrum | aurantiacum | 0 | 0.3 | 0.3 |
| Cof | Shrubs | Cordyline | fruticosa | 10.6 | 0.2 | 10.8 |
| Dp | Shrubs | Duranta | plumieri | 0.1 | 0.3 | 0.4 |
| Js | Shrubs | Jasminum | sambac | 0 | 0.4 | 0.4 |
| Lo | Shrubs | Lavandula | angustifolia | 0.1 | 28.9 | 29.1 |
| Pz | Shrubs | Pelargonium | zonal | 2.8 | 1 | 3.8 |
| Ob | Shrubs | Ocimum | basilicum | 0.3 | 63.2 | 63.5 |
| Sr | Shrubs | Strelitzia | reginae | 11.1 | 0.2 | 11.3 |
| Bs | Climbers | Bougainvillea | stans | 0.1 | 0.6 | 0.7 |
| Catr | Ground-covers | Catharanthus | roseus | 0.1 | 1 | 1.1 |
| Lac | Ground-covers | Lantana | camara nana | 0 | 0.6 | 0.6 |
| Ov | Ground-covers | Origanum | vulgare | 4.2 | 1.6 | 5.8 |
| Pp | Ground-covers | Pelargonium | peltatum | 7 | 2.6 | 9.7 |
| Pv | Ornamental Grasses | Paspalum | vaginatum | 0 | 0.1 | 0.1 |
| | | Total | | 200.7 | 317 | 517.6 |

4- Oxygen Production

Table (61) Oxygen Production of Individual Trees and for total plantation, Source: Author from i-Tree Eco

| Tree ID | Type | Genus | Species | Per Tree | | | Number of Trees | Per Total Planted species | | |
|---------|--------------------|---------------|--------------|---------------|------------------------------|-----------------------------|-----------------|---------------------------|------------------------------|-----------------------------|
| | | | | Oxygen (kg) | Carbon Sequestration (kg/yr) | Leaf Area (m ²) | | Oxygen (kg) | Carbon Sequestration (kg/yr) | Leaf Area (m ²) |
| Pd | Palms | Phoenix | dactylifera | 0.41 | 0.15 | 51.4 | 2 | 0.82 | 0.3 | 102.8 |
| Al | Trees | Azadirachta | indica | 4.01 | 1.5 | 400 | 35 | 140.35 | 52.5 | 14000 |
| Cag | Trees | Cassia | glauc | 52.71 | 19.77 | 183.4 | 35 | 1844.85 | 691.95 | 6419 |
| Dr | Trees | Delonix | regia | 74.36 | 27.88 | 196.3 | 30 | 2230.8 | 836.4 | 5889 |
| Jo | Trees | Jacaranda | mimosifolia | 73.47 | 27.55 | 486.9 | 12 | 881.64 | 330.6 | 5842.8 |
| Spc | Trees | Spathodea | campanulata | 32.99 | 12.37 | 403.3 | 25 | 824.75 | 309.25 | 10082.5 |
| Cg | Shrubs | Carissa | grandiflora | 7.61 | 2.85 | 8 | 16 | 121.76 | 45.6 | 128 |
| Cea | Shrubs | Cestrum | aurantiacum | 2.71 | 1.02 | 3.8 | 80 | 216.8 | 81.6 | 304 |
| Cof | Shrubs | Cordyline | fruticosa | 1.62 | 0.61 | 1.9 | 30 | 48.6 | 18.3 | 57 |
| Dp | Shrubs | Duranta | plumieri | 3.31 | 1.24 | 2.3 | 95 | 314.45 | 117.8 | 218.5 |
| Js | Shrubs | Jasminum | sambac | 2.91 | 1.09 | 5 | 80 | 232.8 | 87.2 | 400 |
| Lo | Shrubs | Lavandula | angustifolia | 3.31 | 1.24 | 2.4 | 50 | 165.5 | 62 | 120 |
| Pz | Shrubs | Pelargonium | zonal | 5.06 | 1.895 | 5.8 | 100 | 506 | 189.5 | 580 |
| Ob | Shrubs | Ocimum | basilicum | 8.31 | 3.12 | 5.2 | 110 | 914.1 | 343.2 | 572 |
| Sr | Shrubs | Strelitzia | reginae | 1.62 | 0.61 | 2 | 100 | 162 | 61 | 200 |
| Bs | Climbers | Bougainvillea | stans | 2.73 | 1.02 | 3.8 | 15 | 40.95 | 15.3 | 57 |
| Catr | Ground-covers | Catharanthus | roseus | 2.71 | 1.02 | 3.6 | 4000 | 10840 | 4080 | 14400 |
| Lac | Ground-covers | Lantana | camara nana | 8.31 | 3.12 | 5.1 | 1400 | 11634 | 4368 | 7140 |
| Ov | Ground-covers | Origanum | vulgare | 3.94 | 1.48 | 2.9 | 1280 | 5043.2 | 1894.4 | 3712 |
| Pp | Ground-covers | Pelargonium | peltatum | 5.06 | 1.895 | 5.8 | 100 | 506 | 189.5 | 580 |
| Pv | Ornamental Grasses | Paspalum | vaginatum | 0.16 | 0.06 | 1.1 | 3500 | 560 | 210 | 3850 |
| | | Total | | 297.32 | 111.49 | 1780 | 11095 | 37229.37 | 13984.4 | 74654.6 |

3.2 Fauna

Primary Analysis

From site visits no specific fauna species was observed in the project's site due to non-existing of any plant species or water bodies. Rarely some ants, bees and mosquitos were seen.

Performance Analysis expectation

A study was done to measure the expected analysis of the fauna in the location, due to the introduction of different flora species and the waterway. The primary expectations for fauna enrichment due to suggested plants introduced, where the following species were expected: **Butterflies, Birds, Bees, Mosquito, Lizards, toads, cats and dogs**. The waterway also affords suitable habitat for various **microorganisms**, which help in the purification of the water quality of the wetland water pathway.

In addition to the shading trees that afford nice climate for cats and dogs to shelter from sunny hard weather, the flora species that help in the enrichment for those fauna species are:

| | |
|---|--|
| Cestrum aurantiacum Syn. C. chaculanum | Strongly scented flowers Attracts butterflies Eliminate mosquito in specific zones |
| Duranta plumieri Syn. D. repens | Attractive color for borders Bloom repeatedly in Spring and Summer Attracts butterflies and birds |
| Lanvandula angustifolia Syn. L. officinalis | Aromatic Flower and leaf Attracts butterflies and bees; Biodiversity |
| Lantana camara nana | Blooming all year Aromatic Flower and Leaf Attracts butterflies and bees, Biodiversity |
| Origanum vulgare Syn. majorana | Aromatic perennial herb Attracts butterflies and bees, Biodiversity |
| Pelargonium peltatum | Blooming 7 months Attracts butterflies and bees, Biodiversity |

Table (62) Role of some vegetation species in enriching fauna, Source: Author

A comparable study of the introduced species at Wadi Hanifah Park at a similar Arid climate, it is suggested that similar type of species could be introduced to the park. Those species are: (Trottier, J., et al., 2015)

15 bird species, 9 fish species, 3 mollusk species, 2 amphibian species, and 3 reptile species

- **Birds:** Bittern, egret, mallard duck, heron, long-beaked bird sp. (unidentified), moorhen, black-winged stilt, woodpecker, eagle, seagull, mynah, house sparrow, spotted dove, pigeon, kingfisher
- **Fish:** Tilapia, African jewelfish (cichlid), molly (sailfin and black-spotted), gambusia (mosquito fish), African and sucker mouth catfish, koi carp
- **Mollusks:** Melanoide snail, ram horn snail, Asian clam
- **Amphibians:** Frog sp., turtle sp.
- **Reptiles:** Common house gecko, Arabian spiny-tailed lizard, water snake
- **Insects:** Grasshopper, dragonfly, honeybee

The freshwater fauna in Egypt is dominated by tilapia species which make the majority of fish catch. Many Nile species also inhabit the lakes, such as *Hydrocynus forskalii*, *Lates niloticus*, *Cyprinus carpio*, *Barbus bynni*, *Clarias lazara*, *C. gariepinus*, *Bagrus bayad* and *Lates niloticus*. Several freshwater tolerant marine species are also found in the Delta lakes, including mullets, soles, seabream, seabass, meager, eels and shrimp.

The presence of water and vegetation offer a quite suitable site for an ecological habitat creation. Attracting wildlife species, particularly birds, and creating a green area. This is exactly one of the main characteristics of CW Parks. (Stefanakis, A., et al., 2014)

Currently experimental studies are being performed to suggest the appropriate fish species, both ornamental and productive species, to be introduced to the Fishponds in the park.

Limitations

The expectation studies are limited to comparative parks in arid climate and prediction of the available species in Egypt. No mammals were included, except for cats and dogs as they are already existing in adjacent locations, as the wetland is designed as park that has vegetation borders to afford safety for the visitors.

4. Water

4.1 Water Reused

Primary Analysis

The project main purpose is the reuse of wastewater from the sewage treatment plant adjacent to the project location. The project proposed plan is to reuse an average daily amount of minimum 200 m³/day and reaching maximum of 400 m³/day.

Performance Analysis expectation

The expected analysis of the water reused in the location is the purification of minimum 200 m³/day and reaching maximum of 400 m³/day. The treated water is expected to be reused for:

- Irrigation of the planted vegetation of the park
- Filled in the pond reservoir at Zone 4 (Capacity of 800 m³)
- Resale to the municipality for irrigation of adjacent residential settlements landscape area's locations
- Fishponds for ornamental species
- Future Water re-use plans of the project includes Agricultural use for productive crops and productive Fishponds (More studies are to be implemented after being experimented)

Vegetations' Hydrology Effects

Table (63) Hydrology Effects by Individual Trees, Source: Author from i-Tree Eco

| Tree ID | Type | Genus | Species | Hydrology Effects by Individual Trees | | | | | | |
|--------------|--------------------|---------------|--------------|---------------------------------------|------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| | | | | Leaf Area | Potential Evapotranspiration | Evaporation | Transpiration | Water Intercepted | Avoided Runoff | Avoided Runoff Value |
| | | | | (m ²) | (m ³ /yr) | (m ³ /yr) | (m ³ /yr) | (m ³ /yr) | (m ³ /yr) | (\$/yr) |
| Pd | Palms | Phoenix | dactylifera | 51.4 | 12.9 | 0.2 | 4.3 | 0.2 | 0 | 0.08 |
| Ai | Trees | Azadirachta | indica | 400 | 100.6 | 1.6 | 33.7 | 1.6 | 0.3 | 0.64 |
| Cag | Trees | Cassia | glauca | 183.4 | 46.1 | 0.7 | 15.5 | 0.7 | 0.1 | 0.3 |
| Dr | Trees | Delonix | regia | 196.3 | 49.4 | 0.8 | 16.6 | 0.8 | 0.1 | 0.32 |
| Jo | Trees | Jacaranda | mimosifolia | 486.9 | 119.9 | 1.9 | 41.1 | 1.9 | 0.3 | 0.78 |
| Spc | Trees | Spathodea | campanulata | 403.3 | 101.4 | 1.6 | 34 | 1.6 | 0.3 | 0.65 |
| Cg | Shrubs | Carissa | grandiflora | 8 | 2 | 0 | 0.7 | 0 | 0 | 0.01 |
| Cea | Shrubs | Cestrum | aurantiacum | 3.8 | 1 | 0 | 0.3 | 0 | 0 | 0.01 |
| Cof | Shrubs | Cordyline | fruticosa | 1.9 | 0.5 | 0 | 0.2 | 0 | 0 | 0 |
| Dp | Shrubs | Duranta | plumieri | 2.3 | 0.6 | 0 | 0.2 | 0 | 0 | 0 |
| Js | Shrubs | Jasminum | sambac | 5 | 1.2 | 0 | 0.4 | 0 | 0 | 0.01 |
| Lo | Shrubs | Lavandula | angustifolia | 2.4 | 0.6 | 0 | 0.2 | 0 | 0 | 0 |
| Pz | Shrubs | Pelargonium | zonal | 3.3 | 0.8 | 0 | 0.3 | 0 | 0 | 0.01 |
| Ob | Shrubs | Ocimum | basilicum | 5.2 | 1.3 | 0 | 0.4 | 0 | 0 | 0.01 |
| Sr | Shrubs | Strelitzia | reginae | 2 | 0.5 | 0 | 0.2 | 0 | 0 | 0 |
| Bs | Climbers | Bougainvillea | stans | 3.8 | 1 | 0 | 0.3 | 0 | 0 | 0.01 |
| Catr | Ground-cover | Catharanthus | roseus | 3.6 | 0.9 | 0 | 0.3 | 0 | 0 | 0.01 |
| Lac | Ground-cover | Lantana | camara nana | 5.1 | 1.3 | 0 | 0.4 | 0 | 0 | 0.01 |
| Ov | Ground-cover | Origanum | vulgare | 2.9 | 0.7 | 0 | 0.3 | 0 | 0 | 0 |
| Pp | Ground-cover | Pelargonium | peltatum | 8.3 | 2.1 | 0 | 0.7 | 0 | 0 | 0.01 |
| Pv | Ornamental Grasses | Paspalum | vaginatum | 1.1 | 0.3 | 0 | 0.1 | 0 | 0 | 0 |
| Total | | | | 1,780 | 447.7 | 7.1 | 154.4 | 7.1 | 1.2 | 2.89 |

- Reduces potable water consumption by 200 m³ per day with the use of treated urban wastewater for park amenities and irrigation.
- Avoided runoff value is calculated by the price \$2.361/m³. The user-designated weather station reported 15.1 centimeters of total annual precipitation.
- Eco will always use the hourly measurements that have the greatest total rainfall or user-submitted rainfall if provided.

4.2 Water Quality:

Primary Analysis

A primary 3 study samples were collected to measure the primary analysis of the water quality of the water inflow from the sewage treatment system adjacent to the location. The following data were collected:

Table (64): Water quality data sampled on 06-07-2020, Source: Designers Academic team's 2nd report

| Treatment stage | | Unit | Sample 1 | Sample 2 | Sample 3 |
|-----------------------------------|------------------------|-----------|---------------------|---------------------|---------------------|
| Physicochemical Parameters | | | | | |
| pH Lab | pH | - | 7.19 | 7.70 | 7.60 |
| Carbonate | CO₃ | mg/l | 0 | 0 | 0 |
| Bicarbonate | HCO₃ | mg/l | 419 | 246 | 241 |
| Total Alkalinity | | mg/l | 419 | 246 | 241 |
| Electrical Conductivity Lab | EC | mmhos/cm | 1.505 | 1.326 | 1.312 |
| Total Dissolved Solids | TDS | mg/l | 964 | 848 | 839 |
| Biochemical Oxygen Demand | BOD | mg/l | 300 | 11 | 10 |
| Chemical Oxygen Demand | COD | mg/l | 502 | 34.7 | 34.4 |
| Ammonia | NH₃ | mg/l | 10.50 | 1.7 | 1.8 |
| Major Cations | | | | | |
| Calcium | Ca | mg/l | 71.05 | 66.24 | 64.32 |
| Potassium | K | mg/l | 38 | 36 | 36 |
| Magnesium | Mg | mg/l | 17.78 | 16.81 | 17.20 |
| Sodium | Na | mg/l | 186 | 184 | 186 |
| Major Anions | | | | | |
| Flouride | F | mg/l | 0.47 | 0.43 | 0.40 |
| Chloride | Cl | mg/l | 209.9 | 205.9 | 207.9 |
| Nitrite | NO₂ | mg/l | <0.2 | 0.24 | 0.20 |
| Nitrate | NO₃ | mg/l | 0.48 | 0.96 | 0.96 |
| Sulfate | SO₄ | mg/l | 39.0 | 111.3 | 109.2 |
| Trace Metals | | | | | |
| Aluminum | Al | mg/l | 0.143 | 0.019 | <0.007 |
| Antimony | Sb | mg/l | <0.009 | <0.009 | <0.009 |
| Arsenic | As | mg/l | <0.006 | <0.006 | <0.006 |
| Barium | Ba | mg/l | 0.027 | 0.007 | 0.007 |
| Cadmium | Cd | mg/l | <0.002 | <0.002 | <0.002 |
| Chromium | Cr | mg/l | 0.016 | <0.002 | <0.002 |
| Cobalt | Co | mg/l | <0.003 | <0.003 | <0.003 |
| Copper | Cu | mg/l | <0.006 | <0.006 | <0.006 |
| Iron | Fe | mg/l | 0.253 | <0.006 | <0.006 |
| Lead | Pb | mg/l | <0.007 | <0.007 | <0.007 |
| Manganese | Mn | mg/l | 0.248 | 0.036 | 0.029 |
| Nickel | Ni | mg/l | 0.014 | 0.008 | 0.007 |
| Selenium | Se | mg/l | <0.007 | <0.007 | <0.007 |
| Tin | Sn | mg/l | <0.006 | <0.006 | <0.006 |
| Vanadium | V | mg/l | <0.001 | <0.001 | <0.001 |
| Zinc | Zn | mg/l | <0.005 | <0.005 | <0.005 |
| Microbiological Parameters | | | | | |
| Total Coliform | | CFU/100ml | 240X10 ⁴ | 320X10 ² | 420X10 ² |
| Fecal Coliform | | CFU/100ml | 80X10 ⁴ | 100X10 ² | 120X10 ² |

According to the team's report, most of the trace elements concentration are under detection limit

Performance Analysis expectation

The proposed purification system has been simulated by the mechatronic and hydrology project's team according to laboratory tests. According to their simulation results high degree of water purification is expected to be achieved by the proposed system and considering other changes and factors. Reduction of high levels of BOD, suspended solids and nitrogen is expected, in addition to substantial levels of metals, trace organic and pathogens.

Water Treatment proposed quality

Design of the proposed wetland treatment system is for the following water quality elements, *Source: Designers Academic team's 2nd report*

- **BOD** = 300 mg/l
- **TDS** = 964 mg/l
- **Ammonia** = 10.5 mg/l
- **TSS** = 214 mg/l (2nd week of June)
- **TN** = 15 mg/l (estimated)
- **TP** = 3 mg/l (estimated)
- **Fe** = 0.253 mg/l
- **Mn** = 0.248 mg/l

Water Treatment system Design

1- Physical dimensions

- **Length** = 600 m
- **Width** = 5 m
- **Depth** = 1 m

Discharge = 20 m³/day = 0.00231 m³/sec

2- Meteorological Data: Temperature = 30 °C

3- Design parameters:

- **TSS** Settling Velocity = 0.1 m/day
- **BOD** Decay Rate @ 20 Deg. Celsius = 20 /day
- **BOD** Temperature Correction Factor = 1.047
- Total Nitrogen (TN) Removal Rate @ 20 Deg. Celsius = 0.05 /day
- TN Temperature Correction Factor = 1.045

4- Detention time

Time duration of water in the treatment system depends on the size of the tank and the amount of water entering the treatment. For an average volume of 200 m³/day, Detention time = 15 days

Removal Efficiency

Table (65): Water quality removal Efficiency, Source: Designers Academic team's 2nd report

| | |
|------------------------------------|----------|
| TSS Removal Efficiency: | 76.37 % |
| Total Coliform Removal Efficiency: | 99.999 % |
| BOD Removal Efficiency: | 99.99 % |
| TN Removal Efficiency: | 68.87 % |
| TP Removal Efficiency: | 30.05 % |

Velocity = 0.05 m/sec

Expected Inflow and Outflow concentrations

Table (66): Expected Inflow and Outflow concentrations, Source: Designers Academic team's 2nd report

| Water Quality | Unit | Inflow Concentrations | Outflow Concentrations |
|----------------|------------|-----------------------|------------------------|
| TSS | mg/L | 214 | 50.56 |
| BOD | mg/L | 300 | 0.03554 |
| TN | mg/L | 15 | 4.669 |
| TP | Mg/l | 3 | 2.098 |
| Total Coliform | MPN/100 ml | 2,400,000 | 24 |
| Fe | mg/L | 0.253 | 0.1846 |
| Mn | mg/L | 0.248 | 0.181 |

According to the team's analysis report, the expected water quality would be appropriate for irrigation of ornamental plants, see Table (54) Ornamental plants suggested for planting of project park according to the water quality.

Irrigation concept

According to the second report of the designers' academic team, the project's mechatronic and hydraulic group conducted a simulation study utilizing software Pump Calculator 2015 - V 2. A proposed irrigation system includes two flow branches, one on each side of the park. For each flow branch on the park's two sides, a 10-horsepower centrifugal pump serves 160 sprinklers. The sprinklers are fed by ten **internal** branch pipelines of 80 meters in length and [32-63] mm in diameter, which branch from ten **external** branch pipelines of 0.5 meters in length and 50 mm in diameter, which extend from ten 1.5-inch valves along the main pipeline of 800 meters in length and 63 mm in diameter to cover the entire park area.

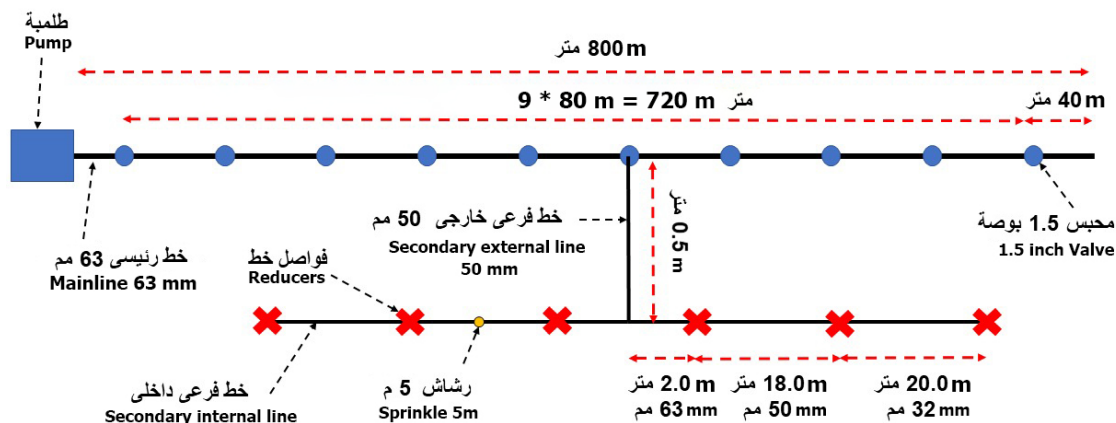


Fig. (165) Irrigation concept for treated water reuse,

Source: Edited by Author from Mechanical team, Designers Academic team's 2nd report

6.5. Park's Performance Analysis expectation

Material

- Use of existing material of the excavation of the water path as backfilling for the construction of the hill and the different levels inside the garden, that offers green space which provides scenic views and various recreational opportunities
- Use of natural stone and local materials
- Hardscape is designed of various types of natural materials in the pedestrian trail
- Regional sourcing of soil, plants, and constructing materials



Fig. (166) Park's material use renderings, Source: Design Academic team

Public Open Space

- Providing water treatment while creating a distinctive public open-space attraction.
- Various exploration network for visitors through different path materials
- Creating an attractive water features and pathway
- Engaging visitors, through pedestrian pathways closer to an educational natural experience.
- Increasing public open space through various spaces and zones
- Educational experience through descriptive signage of species and ecological process of the park
- Circulating pedestrian paths around the site and through the wetland
- Numerous platforms and thresholds for access to water and aesthetic views
- Diversity of vegetation species of colorful native perennials ensuring seasonal themes
- Diverse aesthetic qualities and ecological functions



Fig. (167) Park's Open space renderings, Source: Design Academic team

Public Recreational areas

- Respecting cultural and social values in the park's design and offering family compartments, and semi-enclosed areas that respect users' privacy
- Early public participation, by developing the first phase as major part of the park while adjacency to the community ensures a strong connection to the neighborhood in the future.
- Providing various recreational opportunities to residents and visitors for vibrant experience
- Engaging visitors with the water through twisting pathways
- Overlapping pedestrian pathways along the wetland path creates thresholds for visual aesthetic interest
- Educational and informative signs to educate about natural patterns, processes, and native species
- Opportunities for recreation, education, and research.
- Nodes on the pedestrian network create areas for resting and gathering
- Providing a recreational outdoor for all age visitors and for a variety of different activities
- Interpretive signage at the entrance of the park for wayfinding and educational purposes



Fig. (168) Recreational Areas renderings, Source: Design Academic team

Impressive Features

- Various levels offering distinct prospects for different activities and dynamic user experience in the park
- Routing pedestrian shaded pathways enhance the visitors' interaction with water, plants and wildlife
- Descriptive interactive signage of species and ecological process of the park'
- Series of thresholds and visual aesthetic interest for a dynamic experience
- Opportunities for recreation, education, and research for the various visitors' group age needs
- Hill covered with native trees, shrubs, and cactus to create a barrier and in addition to providing aesthetic nature scene.
- Distinct colorful vegetation species to offer shade, habitat and aesthetic values
- Interconnected pedestrian path network creates unique circulation, privacy, and activity experience



Fig. (169) Impressive Features renderings, Source: Design Academic team

Landscaping Important features

- Enriching the aesthetic value with greenery and water features.
- Development of various landscape features to offer diverse aesthetic usage of the park, such as:
 - **Stone and rock features** to introduce an interesting natural feel
 - **Planting of native vegetation** of palm trees and various ornamental indigenous species of flora
 - **Landscaping of diverse zones** with various themes for interactive experience
 - **Interpretative trails** to allow public to access and guiding to places of interest
 - **Interesting ambience with lighting** to show certain features that bring an interesting look.
 - **Hill features** for the creation of interesting and aesthetic scenery landscape
 - **Designing of lakes, ponds and parks** for recreational purposes and dynamic user experience
 - **Respecting social and religious value** by offering Prayer areas, Toilet blocks, and activity booths
 - **Interpretative signage** for guidance through the park
- Designing a lookout point to enjoy beautiful scenery with natural structures
- Designing routing shaded pathways to increases interactions with diverse wetland plants and wildlife
- Diversity of plant species with various colors for a unique seasonally "messy" aesthetic experience.
- Understanding the needs of surrounding community and employing an interactive experience
- Aesthetic ecological park that adheres to environmental ethics with sense of ecological awareness
- Interconnected pedestrian circulation with wetland and nodes provides views and gathering areas
- Solar powered lighting reduces the site's energy consumption.
- Educational signage as an educational opportunity for visitors about vegetation species and zones and wetland treatment process.



Fig. (170) Landscape renderings, Source: Design Academic team

BEFORE

AFTER

Expected Achievement



Fig. (171) Former site: a desertic ribbon adjacent to sewage plant radius of 2km is brownfield planned for park's extension
Source: Author, Date Taken: August 7, 2021, at 15:37



Fig. (172) Expected Park site: A Multifunctional recreational Park
Potentials of economic revenue, increased recreational & Social Activities
Source: Design Academic team

Water

- Water quality improvement to be suitable for landscape irrigation using only biological processes
- Series of water features and ponds offer scenic and recreational value
- Water features recharged with treated water for efficient water reuse
- Landscape irrigation through treated water
- Possible rainwater runoff harvesting and treatment in the constructed wetland.

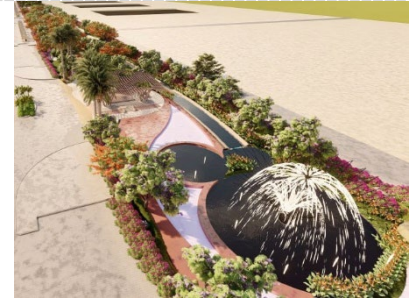


Fig. (173) Water features renderings, Source: Design Academic team

Flora

- Introducing indigenous species of shading trees, ornamental shrubs and aromatic perennials
- Planting more than 11095 plant, shrubs and perennials.
- Increasing the habitat value of the site through diversity of vegetation of mainly native species to create various wildlife habitats
- Introducing 21 vegetation species; 1 Palm species, 5 tree species, 9 shrubs, 4 ground covers, 1 climber species and 1 Ornamental Grass species
- Total vegetation of 11095 plant, represented in 2 Palms, 137 Trees, 661 Shrubs, 15 Climbers, 6780 Groundcovers, and 3500 Ornamental Grasses
- Allowing plant communities to evolve and adapt over time
- Evergreen species with low water requirement, and tolerance for high pollution, drought and solar



Fig. (174) Flora Enhancement renderings, Source: Design Academic team

Fauna inventory

- Increasing animal species by enriching the environment with diverse indigenous habitat of various fauna
- Enriching quality of fauna species is also expected due to the introduction of various flora species



Fig. (175) Fauna Enhancement renderings, Source: Design Academic team

Area Re-naturalized

- Establishing natural functions and dynamic processes of adaptation and succession
- Introducing water features
- Creating diverse habitats requiring minimal management.
- Careful planning and plant selection, species trialing, progress monitoring for best performance
- Enriching quality of flora and fauna species



Fig. (176) Park's area re-naturalized renderings, Source: Design Academic team

Strategies

- **Environmental Strategies:**

- Construction of water treatment system and wetland based on existent resources of the adjacent sewage treatment plant
- Introduction of native plant species, 11095 plant reduce pollution and enhance air quality
- Introduced vegetation absorbs carbon dioxide, purify contaminated land and water
- Rainwater harvesting
- Provide habitat for native plant and animal

- **Environmental & Economic Strategies:** Waste Treatment/ Recycling and utilization

- **Social Strategies:**

- Create green space for public recreation
- Create pedestrian path system with recreational and educational experience

- **Environmental & Social Strategies:** Hardscape pedestrian trail of natural stone and local materials

- **Economic Strategies:** Low maintenance, Cost saving, Enhance the land value

SOCIAL

- Attracting neighboring community and other visitors through offering a unique and interactive experiences and through designing various thematic zones and ensuring their acceptance.
- Encouraging community engagement through various activities and aesthetic values
- Provides Park access for the nearby residents within a 15-minute walking distance
- Serving various age groups of visitors through distinct activities for seniors, adults and children
- Provides educational opportunities for nearby schools and summer activities vacation programs
- Improves ecological awareness and environmental consciousness of park visitors
- Provide recreation and educational opportunities to residents and visitors
- Provide safety and social values for residents and visitors
- Enhancing odor reduction by creating green belt and planting of various Scented plantations

Socio/ Economic Benefits

ECONOMY

- Saving of a great cost value through utilizing wastewater sources in irrigation of adjacent landscape instead of using municipality's potable water
- Saving of material cost through reuse of available site materials during park construction
- Saving of energy costs by recycling vegetation wastes in biogas production
- Generating revenue from recreational and facility rental fees in zone 4
- Considered a catalyst project in the new underpopulated city that would encourage economic and social development
- Saving of maintenance cost of weeding, pruning, irrigating, and fertilizing through use of native species with low-maintenance and low water requirements
- Saving of water cost through water treatment and reuse in the irrigation and water features
- Contributing to increase of home value within approximate blocks and increase in land use value
- Ensuring future potentials for Park's and water treatment system upgrading

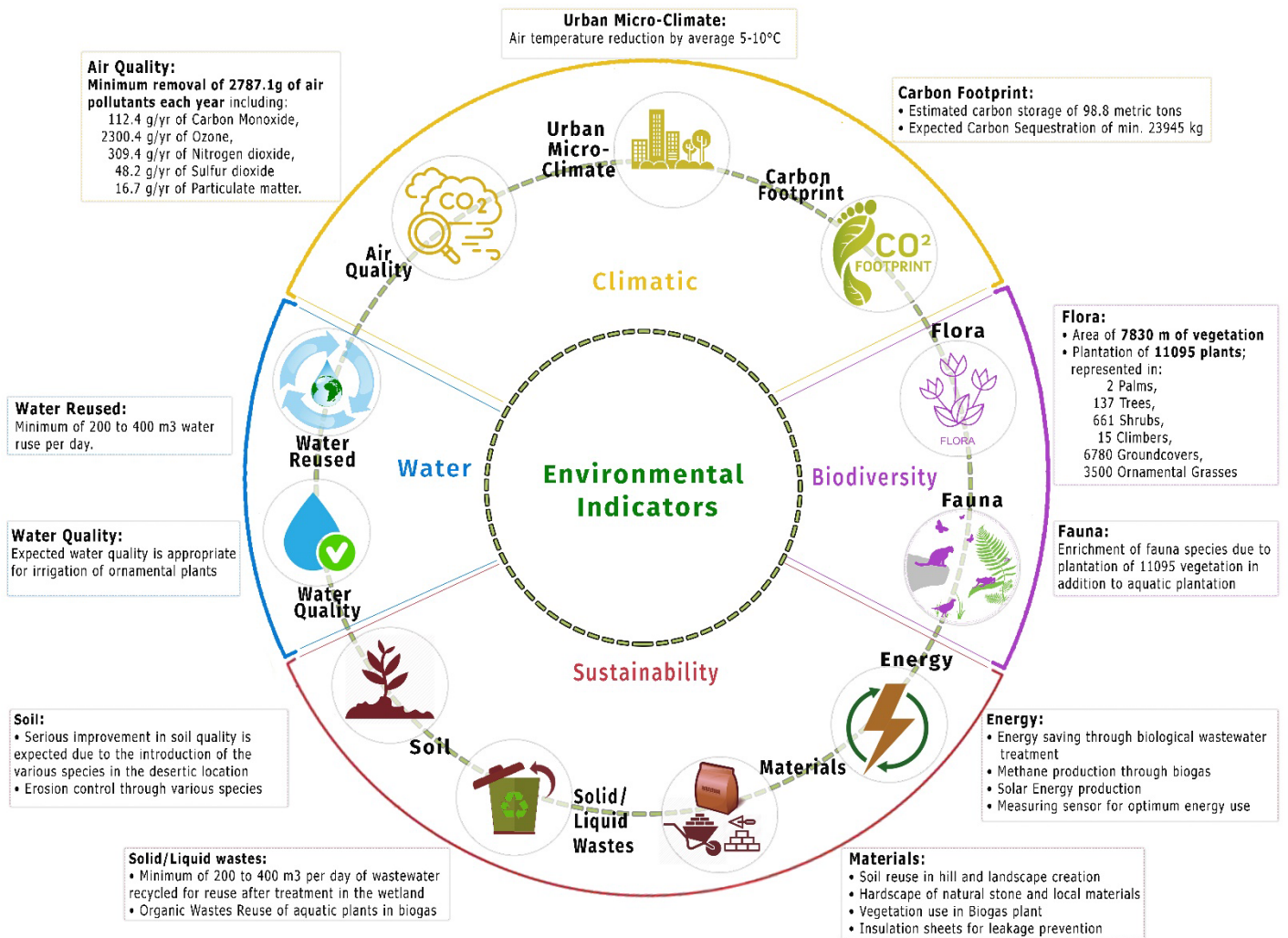
6.6. Case study's Environmental Analysis Summary

Table (67) 10th of Ramadan wetland park's Environmental Analysis Summary Source: By Author

| Category | Indicator | Sub-Indicators /Description | Type | Output |
|-----------------------|---------------------------------|--|--------------|---|
| Environmental Aspects | Climatic Aspects | Air Quality - Air quality: Improvement in air quality due to increased vegetation cover | Quantitative | <ul style="list-style-type: none"> • Minimum removal of 2787.1g of air pollutants each year through the addition of total 11095 vegetation • Pollutants removed included 112.4 g/yr of carbon monoxide, 2300.4 g/yr of ozone, 309.4 g/yr of nitrogen dioxide, 48.2 of sulfur dioxide, and 16.7 g/yr of particulate matter. • Air temperature reduction by average 5-10°C • Estimated carbon storage of 98.8 metric tons • Carbon Sequestration minimum of 23945 kg is expected |
| | | Urban Micro-Climate - Heat Island Effect: % of decrease in Heat Island Effect due to increased vegetation cover and water bodies | Quantitative | |
| | | Carbon Footprint - Carbon Footprint: amount of carbon dioxide and other GHG emissions associated with the wetland project compared to conventional treatment plant | Quantitative | |
| | Sustainability | Energy - Construction Energy Conservation: % of energy conserved during construction stage compared to conventional treatment plant - Operation Energy conservation: % of operational electrical energy conserved compared to conventional treatment operations measured over a specific temporal scale | Quantitative | <ul style="list-style-type: none"> • Energy saving in the treatment process through biological wastewater treatment • Methane production through biogas plants for use as green energy in the electricity for the park • Solar Energy production • Measuring sensor for optimum energy usage |
| | | Materials - Recycled Materials: % of materials that is recycled or acquired from onsite materials - Hazardous Materials: % of hazardous materials and chemicals employed in water treatment process compared to conventional treatment processes | Quantitative | <ul style="list-style-type: none"> • Soil reuse in hill and landscape creation • Hardscape of natural stone and local materials • Vegetation use in Biogas plant • Insulation sheets for leakage prevention |
| | | Solid/ Liquid Wastes - Quality/ Quantity of wastes: % of waste materials discharged during the treatment process | Quantitative | <ul style="list-style-type: none"> • Liquid Wastes Reuse of wastewater inflow from adjacent sewage treatment plant recycled for reuse after purification in the wetland waterway of minimum of 200 to 400 m³ per day. • Organic Wastes Reuse of aquatic plants reused in biogas |
| | | Soil - Quality/ Quantity of soil creation, preservation & restoration: % of fertile or restored soils | Quantitative | <ul style="list-style-type: none"> • Serious improvement in soil quality is expected due to the introduction of the various species in the desertic location • Erosion control through various species |
| | Biodiversity; Habitat Diversity | Flora (Vegetation) - Number of Fauna and Flora species introduced into the habitat | Quantitative | <ul style="list-style-type: none"> • An area of 7830 m of plantation is designed from the total park area • Addition of total of 11095 vegetation, represented in 2 Palms, 137 Trees, 661 Shrubs, 15 Climbers, 6780 Groundcovers, and 3500 Ornamental Grasses |
| | | Fauna - Number of Fauna and Flora species introduced into the habitat | Quantitative | <ul style="list-style-type: none"> • Enrichment of fauna species due to plantation of 11095 vegetation |
| | Water | Water Reused - Water Reused: % of water reused or reintroduced to the irrigation system. | Quantitative | <ul style="list-style-type: none"> • Minimum of 200 to 400 m³ water reuse per day. |
| | | Water Quality - Water quality: % of pathogens removed through the constructed wetland | Quantitative | <ul style="list-style-type: none"> • Expected water quality is appropriate for irrigation of ornamental plants, |

Fig. (177) Expected 10th of Ramadan Wetland Park's Environmental performance summary,

Source: Author



6.7. Applying the Developed Assessment System

Fig. (178) Wetland Park Assessment using proposed CWP Index, Source: Author

| Project Title: Project Type: Location: Climatic Zone: Hardiness Zone: Assessment Author: | | | 10 th Ramadan Wetland Constructed Wetland Park 10th City, Cairo Governorate, Egypt, 30°20'17.9"N 31°47'19.2"E Arid Climate, BWh 10 Aya ElMeligy | | | | | | | | | | | | |
|---|---|------------------------------------|---|---|---|---|----------------------------------|------------------------|-------------------------------|---|---|---|----------------------------------|------------------------|-----------|
| Impacts Activities | | | Project Activities | | | | | | | | | | | | |
| | | | Construction Phase | | | | | | Operation Phase | | | | | | |
| Category | | Impact Factors (IF) | Construction Phase Assessment | IV= Impact Value relevance S*M*P*D | EIV= $\sum_{i=1}^n M_i + S_i + P_i + D_i$ Impact Factor Ratio R= IV/EIV | Weight Based on Question naire | IV Weight Relevance (IVWR) | Percentage Achieved | Operation Phase Assessment | IV= Impact Value relevance S*M*P*D | EIV= $\sum_{i=1}^n M_i + S_i + P_i + D_i$ Impact Factor Ratio R= IV/EIV | Weight Based on Question naire | IV Weight Relevance (IVWR) | Percentage Achieved | |
| Environmental Impact Factors | Climatic Aspects | Air Quality | 5 2 | 100 | 0.048520136 | 0.8 | 0.0388161 | 40.00% | 5 2 | 250 | 0.050060072 | 0.9 | 0.0450541 | 100.00% | |
| | | Urban Micro-Climate | 4 2 | 32 | 0.015526443 | 0.7 | 0.0108685 | 12.80% | 5 2 | 250 | 0.050060072 | 0.9 | 0.0450541 | 100.00% | |
| | | Carbon Foot-print | 3 2 | 12 | 0.005822416 | 0.7 | 0.0040757 | 4.80% | 4 2 | 72 | 0.014417301 | 0.8 | 0.0115338 | 28.80% | |
| | | Noise | 0 1 | 0 | 0 | 0.7 | 0 | 0.00% | 2 2 | 12 | 0.002402883 | 0.8 | 0.0019223 | 4.80% | |
| | Sustainability | Energy | 5 2 | 250 | 0.12130034 | 0.7 | 0.0849102 | 100.00% | 5 2 | 250 | 0.050060072 | 0.8 | 0.0400481 | 100.00% | |
| | | Materials | 5 2 | 250 | 0.12130034 | 0.8 | 0.0970403 | 100.00% | 5 2 | 250 | 0.050060072 | 0.8 | 0.0400481 | 100.00% | |
| | | Solid/ Liquid Wastes | 5 2 | 150 | 0.072780204 | 0.8 | 0.0582242 | 60.00% | 5 2 | 250 | 0.050060072 | 0.8 | 0.0400481 | 100.00% | |
| | | Soil | 4 1 | 16 | 0.007763222 | 0.8 | 0.0062106 | 6.40% | 5 2 | 120 | 0.024028835 | 0.8 | 0.0192231 | 48.00% | |
| | Biodiversity | Flora (Vegetation) | 5 2 | 150 | 0.072780204 | 0.9 | 0.0655022 | 60.00% | 5 2 | 250 | 0.050060072 | 0.9 | 0.0450541 | 100.00% | |
| | | Fauna | 4 2 | 64 | 0.031052887 | 0.8 | 0.0248423 | 25.60% | 5 2 | 200 | 0.040048058 | 0.8 | 0.0320384 | 80.00% | |
| | Water | Water Reused | 5 1 | 0 | 0 | 0.9 | 0 | 0.00% | 5 2 | 250 | 0.050060072 | 0.9 | 0.0450541 | 100.00% | |
| | | Water Quality | 5 1 | 0 | 0 | 0.9 | 0 | 0.00% | 5 2 | 200 | 0.040048058 | 0.9 | 0.0360433 | 80.00% | |
| | Socio-Cultural Impact Factors | Community Values | Community Size Served | 2 1 | 4 | 0.001940805 | 0.8 | 0.0015526 | 1.60% | 5 2 | 90 | 0.018021626 | 0.8 | 0.0144173 | 36.00% |
| | | | Community Awareness | 3 1 | 24 | 0.011644833 | 0.8 | 0.0093159 | 9.60% | 4 2 | 96 | 0.019223068 | 0.8 | 0.0153785 | 38.40% |
| | | | Community Acceptance | 4 2 | 72 | 0.034934498 | 0.8 | 0.0279476 | 28.80% | 4 2 | 128 | 0.025630757 | 0.8 | 0.0205046 | 51.20% |
| | | Social Values | Education / Training | 3 1 | 45 | 0.021834061 | 0.8 | 0.0174672 | 18.00% | 4 2 | 160 | 0.032038446 | 0.8 | 0.0256308 | 64.00% |
| Public Participation | | | 2 1 | 16 | 0.007763222 | 0.8 | 0.0062106 | 6.40% | 4 2 | 96 | 0.019223068 | 0.8 | 0.0153785 | 38.40% | |
| Increased Recreational & Social Activities | | | 1 1 | 4 | 0.001940805 | 0.9 | 0.0017467 | 1.60% | 5 2 | 250 | 0.050060072 | 0.9 | 0.0450541 | 100.00% | |
| Added Social, Connectivity & Safety Values | | | 1 1 | 4 | 0.001940805 | 0.8 | 0.0015526 | 1.60% | 5 2 | 250 | 0.050060072 | 0.8 | 0.0400481 | 100.00% | |
| Aesthetic Values | | Visual Aesthetic Value | 1 1 | 4 | 0.001940805 | 0.9 | 0.0017467 | 1.60% | 5 2 | 250 | 0.050060072 | 0.9 | 0.0450541 | 100.00% | |
| | | Odor Reduction Efficiency | 0 1 | 0 | 0 | 0.8 | 0 | 0.00% | 5 2 | 150 | 0.030036043 | 0.8 | 0.0240288 | 60.00% | |
| | | Economic -Technical Impact Factors | Economic Values | Catalyzing Economic Development | 4 1 | 24 | 0.011644833 | 0.8 | 0.0093159 | 9.60% | 4 2 | 120 | 0.024028835 | 0.8 | 0.0192231 |
| Land Use Value | 5 2 | | | 90 | 0.043668122 | 0.8 | 0.0349345 | 36.00% | 5 2 | 150 | 0.030036043 | 0.8 | 0.0240288 | 60.00% | |
| Economic Savings | 5 2 | | | 250 | 0.12130034 | 0.8 | 0.0970403 | 100.00% | 5 2 | 250 | 0.050060072 | 0.8 | 0.0400481 | 100.00% | |
| Potentials of Economic Revenue | 5 2 | | | 0 | 0 | 0.8 | 0 | 0.00% | 5 2 | 150 | 0.030036043 | 0.8 | 0.0240288 | 60.00% | |
| Technical Values | Construction Process Flexibility | | 5 2 | 250 | 0.12130034 | 0.8 | 0.0970403 | 100.00% | | 0 | 0 | 0.8 | 0 | 0.00% | |
| | Operation and Maintenance Process Flexibility | | | 0 | 0 | 0.8 | 0 | 0.00% | 5 2 | 250 | 0.050060072 | 0.8 | 0.0400481 | 100.00% | |
| | Future Potential for Upgrading | | 5 2 | 250 | 0.12130034 | 0.9 | 0.1091703 | 100.00% | 5 2 | 250 | 0.050060072 | 0.9 | 0.0450541 | 100.00% | |

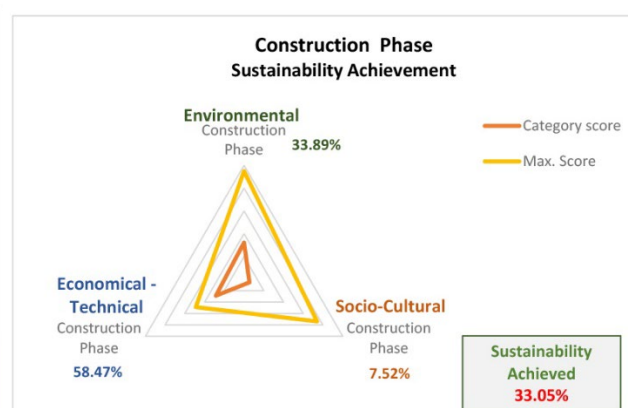
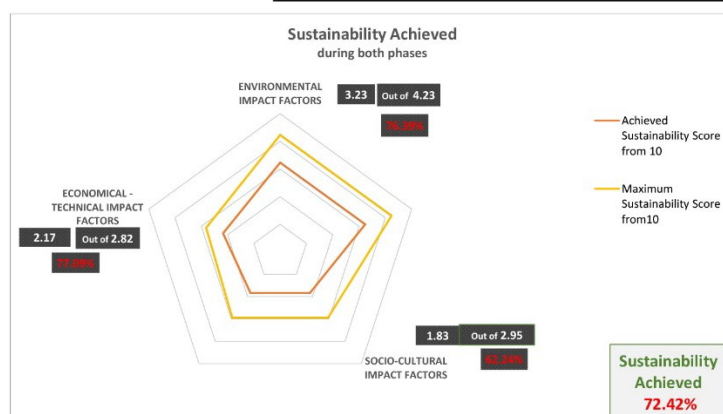
6.7.1. Sustainability Analysis and Representative Charts

Fig. (179) Wetland Park's sustainability analysis, Source: Author

| | | | | | | |
|--------------------|--|--|--|--|--|--|
| Project Title: | | 10th Ramadan Wetland | | | | |
| Project Type: | | Constructed Wetland Park | | | | |
| Location: | | 10th City, Cairo Governorate, Egypt, 30°20'17.9"N 31°47'19.2"E | | | | |
| Climatic Zone: | | Arid Climate, BWh | | | | |
| Hardiness Zone: | | 10 | | | | |
| Assessment Author: | | Aya ElMeligy | | | | |

| nr. | Category | Category Total Score | Max Score | Sustainability Weight from Questionnaire | Sustainability | | |
|-------------------------|--------------------------------------|----------------------|-----------|--|---------------------------------------|--------------------------------------|---------------------|
| | | | | | Achieved Sustainability Score from 10 | Maximum Sustainability Score from 10 | Percentage Achieved |
| 1 | Environmental Impact Factors | 2064 | 2702 | 0.4234 | 3.23 | 4.23 | 76.39% |
| 2 | Socio-Cultural Impact Factors | 1237 | 1988 | 0.2947 | 1.83 | 2.95 | 62.24% |
| 3 | Economical -Technical Impact Factors | 1015 | 1317 | 0.2819 | 2.17 | 2.82 | 77.09% |
| Total Impact Assessment | | | | 1.00 | 7.24 | 10 | 72.42% |

| nr. | | Category | Category score | Max. Score | % | Phase Weight | Category Total Score | Max Score | Percentage Achieved |
|--|---------------------------------------|--------------------|----------------|------------|--------|--------------|----------------------|-----------|---------------------|
| 1 | Environmental Impact Factors | Construction Phase | 805 | 2375 | 33.89% | 0.074 | 2064 | 2702 | 76.39% |
| 2 | | Operation Phase | 2003 | 2525 | 79.33% | 0.926 | | | |
| 3 | Socio-Cultural Impact Factors | Construction Phase | 139 | 1850 | 7.52% | 0.074 | 1237 | 1988 | 62.24% |
| 4 | | Operation Phase | 1226 | 1850 | 66.27% | 0.926 | | | |
| 5 | Economical - Technical Impact Factors | Construction Phase | 716 | 1225 | 58.47% | 0.074 | 1015 | 1317 | 77.09% |
| 6 | | Operation Phase | 961 | 1225 | 78.45% | 0.926 | | | |
| Total Sustainability Achievement in Construction Phase | | | | | | | | | 33.05% |
| Total Sustainability Achievement in Operation Phase | | | | | | | | | 75.24% |

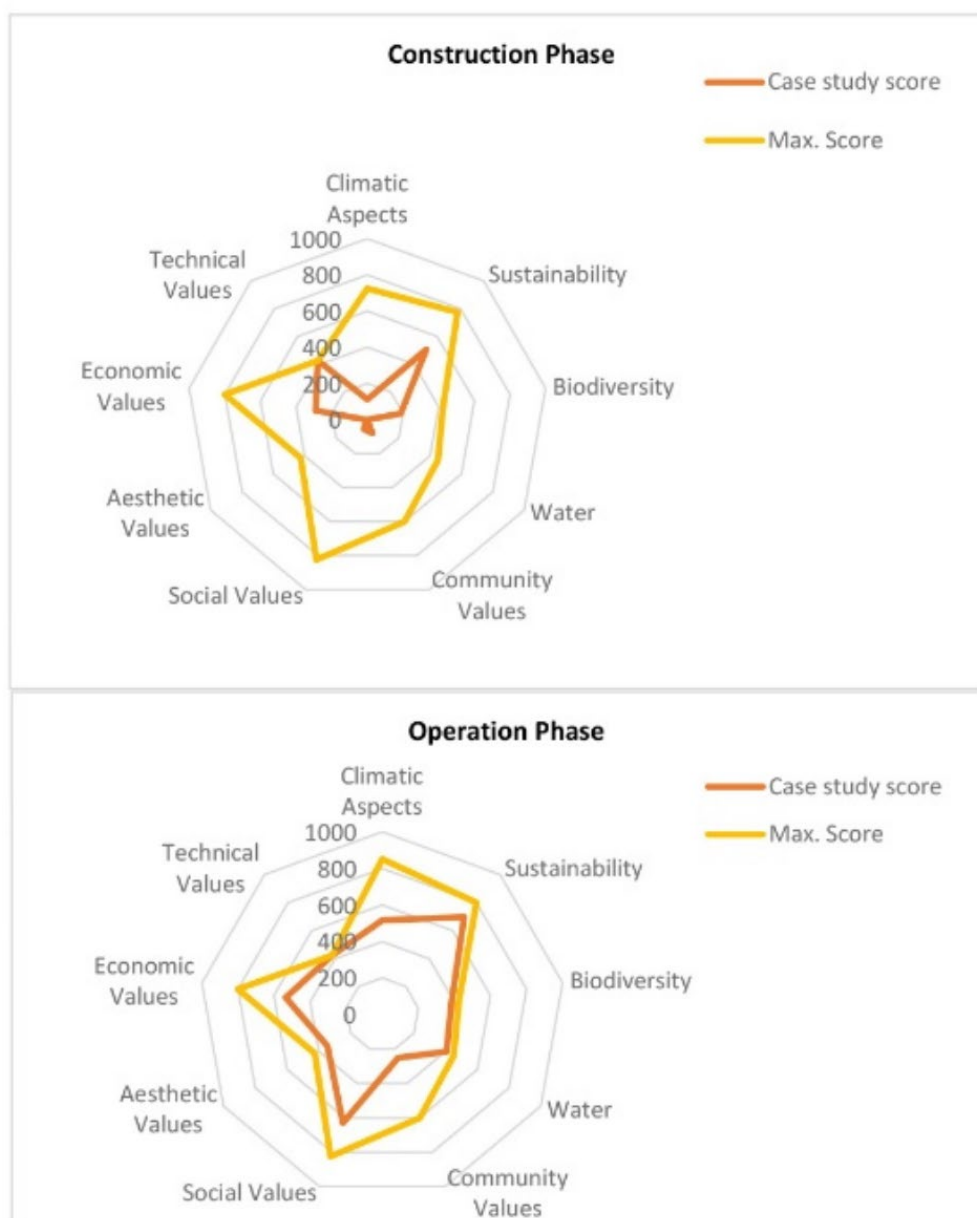


6.7.2. Categories performance Chart

Fig. (180) Wetland Park's Categories performance analysis, Source: Author

| | |
|--------------------|--|
| Project Title: | 10th Ramadan Wetland |
| Project Type: | Constructed Wetland Park |
| Location: | 10th City, Cairo Governorate, Egypt, 30°20'17.9"N 31°47'19.2"E |
| Climatic Zone: | Arid Climate, BWh |
| Hardiness Zone: | 10 |
| Assessment Author: | Aya ElMeligy |

| | | | Construction Phase | | | | | | Construction Phase | | | | | |
|-------------------------|-----------------------------------|------------------|--------------------|------------|------|----------------------|-----------|---------------------|--------------------|------------|------|----------------------|-----------|---------------------|
| nr. | | Category | Case study score | Max. Score | % | Category Total Score | Max Score | Percentage Achieved | Case study score | Max. Score | % | Category Total Score | Max Score | Percentage Achieved |
| 1 | Environmental Impact Factors | Climatic Aspects | 111 | 725 | 15.3 | 805 | 2375 | 33.89% | 517 | 850 | 60.8 | 2003 | 2525 | 79.33% |
| 2 | | Sustainability | 508 | 775 | 65.5 | | | | 696 | 800 | 87 | | | |
| 3 | | Biodiversity | 186 | 425 | 43.8 | | | | 385 | 425 | 90.6 | | | |
| 4 | | Water | 0 | 450 | 0 | | | | 405 | 450 | 90 | | | |
| 5 | Socio-Cultural Impact Factors | Community Values | 80 | 600 | 13 | 139 | 1850 | 7.52% | 251 | 600 | 42 | 1226 | 1850 | 66.27% |
| 6 | | Social Values | 56 | 825 | 7 | | | | 630 | 825 | 76 | | | |
| 7 | | Aesthetic Values | 4 | 425 | 1 | | | | 345 | 425 | 81 | | | |
| 8 | Economic-Technical Impact Factors | Economic Values | 291 | 800 | 36 | 716 | 1225 | 58.47% | 536 | 800 | 67 | 961 | 1225 | 78.45% |
| 9 | | Technical Values | 425 | 425 | 100 | | | | 425 | 425 | 100 | | | |
| Total Impact Assessment | | | | | | 1660 | 5450 | 30.46% | | | | 4190 | 5600 | 74.83% |



6.7.3. Environmental Impact Assessment Chart

Fig. (181) Wetland Park's Environmental Impact Assessment analysis, Source: Author

Project Title: 10th Ramadan Wetland
Project Type: Constructed Wetland Park
Location: 10th City, Cairo Governorate, Egypt, 30°20'17.9"N 31°47'19.2"E
Climatic Zone: Arid Climate, BWh
Hardiness Zone: 10
Assessment Author: Aya ElMeligy

| Assessment Author: Aya Elmelegy | | | | | | | | | | | | | | | |
|---------------------------------|------------------------------|------------------|----------------------|-------------------|------------------|---------------|----------------------------------|------------------|------------------|------------|-----|----------------------------|-----------|------------------------|--------|
| | | | Construction Phase | | | | | | | | | | | | |
| Nr. | Category | Impact Factor | M Magnitude | S Significance | P Probability | D Duration | IV= Impact Value relevance | Factor Weight | Case study score | Max. Score | % | Total Category Score | Max Score | Percentage Achieved | |
| 1 | Environmental Impact Factors | Climatic Aspects | Air Quality | 2 | 5 | 5 | 2 | 100 | 0.8 | 80 | 200 | 40 | 111 | 725 | 15.28% |
| 2 | | | Urban Micro-Climate | 2 | 2 | 4 | 2 | 32 | 0.7 | 22.4 | 175 | 12.8 | | | |
| 3 | | | Carbon Foot-print | 1 | 2 | 3 | 2 | 12 | 0.7 | 8.4 | 175 | 4.8 | | | |
| 4 | | | Noise | 0 | 3 | 0 | 1 | 0 | 0.7 | 0 | 175 | 0 | | | |
| 5 | | Sustainability | Energy | 5 | 5 | 5 | 2 | 250 | 0.7 | 175 | 175 | 100 | 507.8 | 775 | 65.52% |
| 6 | | | Materials | 5 | 5 | 5 | 2 | 250 | 0.8 | 200 | 200 | 100 | | | |
| 7 | | | Solid/ Liquid Wastes | 3 | 5 | 5 | 2 | 150 | 0.8 | 120 | 200 | 60 | | | |
| 8 | | | Soil | 2 | 2 | 4 | 1 | 16 | 0.8 | 12.8 | 200 | 6.4 | | | |
| 9 | | Biodiver sity | Flora (Vegetation) | 3 | 5 | 5 | 2 | 150 | 0.9 | 135 | 225 | 60 | 186 | 425 | 43.81% |
| 10 | | | Fauna | 2 | 4 | 4 | 2 | 64 | 0.8 | 51.2 | 200 | 25.6 | | | |
| 11 | | Water | Water Reused | 0 | 3 | 5 | 1 | 0 | 0.9 | 0 | 225 | 0 | 0 | 450 | 0.00% |
| 12 | | | Water Quality | 0 | 3 | 5 | 1 | 0 | 0.9 | 0 | 225 | 0 | | | |
| Total Environmental Value | | | 805 | | | | | | | 2375 | 805 | 2375 | 33.89% | | |

| | | | Operation Phase | | | | | | | | | | | | |
|---------------------------|------------------------------|------------------|----------------------|-------------------|------------------|---------------|----------------------------------|------------------|------------------|------------|------|----------------------------|-----------|------------------------|--------|
| Nr. | Category | Impact Factor | M Magnitude | S Significance | P Probability | D Duration | IV= Impact Value relevance | Factor Weight | Case study score | Max. Score | % | Total Category Score | Max Score | Percentage Achieved | |
| 1 | Environmental Impact Factors | Climatic Aspects | Air Quality | 5 | 5 | 5 | 2 | 250 | 0.9 | 225 | 225 | 100 | 517 | 850 | 60.85% |
| 2 | | | Urban Micro-Climate | 5 | 5 | 5 | 2 | 250 | 0.9 | 225 | 225 | 100 | | | |
| 3 | | | Carbon Foot-print | 3 | 3 | 4 | 2 | 72 | 0.8 | 57.6 | 200 | 28.8 | | | |
| 4 | | | Noise | 3 | 1 | 2 | 2 | 12 | 0.8 | 9.6 | 200 | 4.8 | | | |
| 5 | | Sustainability | Energy | 5 | 5 | 5 | 2 | 250 | 0.8 | 200 | 200 | 100 | 696 | 800 | 87.00% |
| 6 | | | Materials | 5 | 5 | 5 | 2 | 250 | 0.8 | 200 | 200 | 100 | | | |
| 7 | | | Solid/ Liquid Wastes | 5 | 5 | 5 | 2 | 250 | 0.8 | 200 | 200 | 100 | | | |
| 8 | | | Soil | 3 | 4 | 5 | 2 | 120 | 0.8 | 96 | 200 | 48 | | | |
| 9 | | Biodivers ity | Flora (Vegetation) | 5 | 5 | 5 | 2 | 250 | 0.9 | 225 | 225 | 100 | 385 | 425 | 90.59% |
| 10 | | | Fauna | 4 | 5 | 5 | 2 | 200 | 0.8 | 160 | 200 | 80 | | | |
| 11 | | Water | Water Reused | 5 | 5 | 5 | 2 | 250 | 0.9 | 225 | 225 | 100 | 405 | 450 | 90.00% |
| 12 | | | Water Quality | 4 | 5 | 5 | 2 | 200 | 0.9 | 180 | 225 | 80 | | | |
| Total Environmental Value | | | 2003 | | | | | | | 2525 | 2003 | 2525 | 79.33% | | |



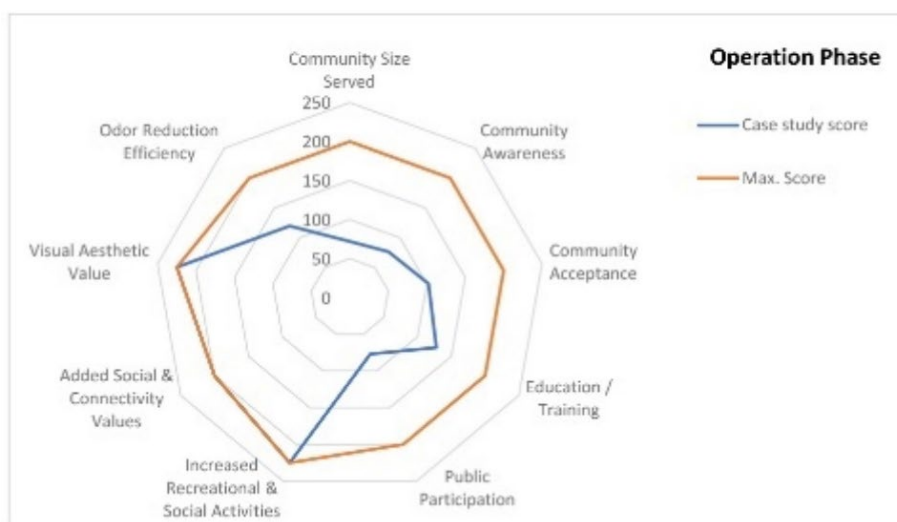
6.7.4. Socio-Cultural Impact Assessment Chart

Fig. (182) Wetland Park's Socio-Cultural Impact Assessment analysis, Source: Author

Project Title: 10th Ramadan Wetland
 Project Type: Constructed Wetland Park
 Location: 10th City, Cairo Governorate, Egypt, 30°20'17.9"N 31°47'19.2"E
 Climatic Zone: Arid Climate, BWh
 Hardiness Zone: 10
 Assessment Author: Aya ElMeligy

| | | | Construction Phase | | | | | | | | | | | | | | |
|----------------------------|-------------------------------|------------------|--|-------------------|------------------|---------------|----------------------------------|------------------|------------------|------------|-----|----------------------------|-----------|------------------------|--------|--|--|
| Nr. | Category | Impact Factor | M Magnitude | S Significance | P Probability | D Duration | IV= Impact Value relevance | Factor Weight | Case study score | Max. Score | % | Total Category Score | Max Score | Percentage Achieved | | | |
| 14 | Socio-Cultural Impact Factors | Community Values | Community Size Served | 1 | 2 | 2 | 1 | 4 | 0.8 | 3.2 | 200 | 1.6 | 80 | 600 | 13.33% | | |
| 15 | | | Community Awareness | 2 | 4 | 3 | 1 | 24 | 0.8 | 19 | 200 | 9.6 | | | | | |
| 16 | | | Community Acceptance | 3 | 3 | 4 | 2 | 72 | 0.8 | 58 | 200 | 28.8 | | | | | |
| 17 | | Social Values | Education / Training | 3 | 5 | 3 | 1 | 45 | 0.8 | 36 | 200 | 18 | 56 | 825 | 6.74% | | |
| 18 | | | Public Participation | 2 | 4 | 2 | 1 | 16 | 0.8 | 13 | 200 | 6.4 | | | | | |
| 21 | | | Increased Recreational & Social Activities | 1 | 4 | 1 | 1 | 4 | 0.9 | 4 | 225 | 1.6 | | | | | |
| 22 | | Aesthetic Values | Added Social & Connectivity Values | 1 | 4 | 1 | 1 | 4 | 0.8 | 3 | 200 | 1.6 | 4 | 425 | 0.85% | | |
| 23 | | | Visual Aesthetic Value | 1 | 4 | 1 | 1 | 4 | 0.9 | 4 | 225 | 1.6 | | | | | |
| 24 | | | Odor Reduction Efficiency | 0 | 2 | 0 | 1 | 0 | 0.8 | 0 | 200 | 0 | | | | | |
| Total Socio-Cultural Value | | | | | | | | | | | 139 | 1850 | 139 | 1850 | 7.52% | | |

| | | | Operation Phase | | | | | | | | | | | | | | |
|----------------------------|-------------------------------|----------------------|--|-------------------|------------------|---------------|----------------------------------|------------------|------------------|------------|------|----------------------------|-----------|------------------------|--------|--|--|
| Nr. | Category | Impact Factor | M Magnitude | S Significance | P Probability | D Duration | IV= Impact Value relevance | Factor Weight | Case study score | Max. Score | % | Total Category Score | Max Score | Percentage Achieved | | | |
| 14 | Socio-Cultural Impact Factors | Community Values | Community Size Served | 3 | 3 | 5 | 2 | 90 | 0.8 | 72 | 200 | 36 | 251 | 600 | 41.87% | | |
| 15 | | Community Awareness | 3 | 4 | 4 | 2 | 96 | 0.8 | 77 | 200 | 38.4 | | | | | | |
| 16 | | Community Acceptance | 4 | 4 | 4 | 2 | 128 | 0.8 | 102 | 200 | 51.2 | | | | | | |
| 17 | | Social Values | Education / Training | 4 | 5 | 4 | 2 | 160 | 0.8 | 128 | 200 | 64 | 630 | 825 | 76.34% | | |
| 18 | | | Public Participation | 3 | 4 | 4 | 2 | 96 | 0.8 | 77 | 200 | 38.4 | | | | | |
| 21 | | | Increased Recreational & Social Activities | 5 | 5 | 5 | 2 | 250 | 0.9 | 225 | 225 | 100 | | | | | |
| 22 | | | Added Social & Connectivity Values | 5 | 5 | 5 | 2 | 250 | 0.8 | 200 | 200 | 100 | | | | | |
| 23 | | Aesthetic Values | Visual Aesthetic Value | 5 | 5 | 5 | 2 | 250 | 0.9 | 225 | 225 | 100 | 345 | 425 | 81.18% | | |
| 24 | | | Odor Reduction Efficiency | 3 | 5 | 5 | 2 | 150 | 0.8 | 120 | 200 | 60 | | | | | |
| Total Socio-Cultural Value | | | | | | | | | | 1226 | 1850 | | 1226 | 1850 | 66.27% | | |



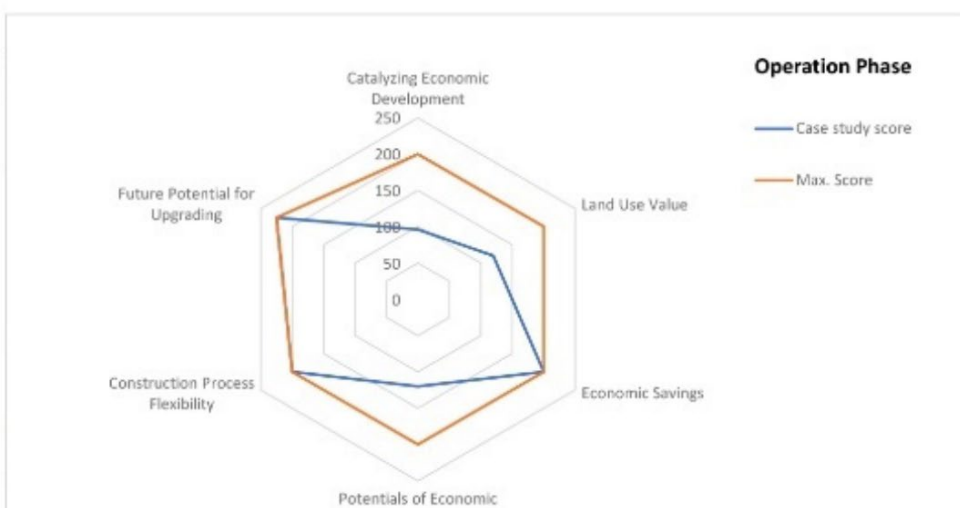
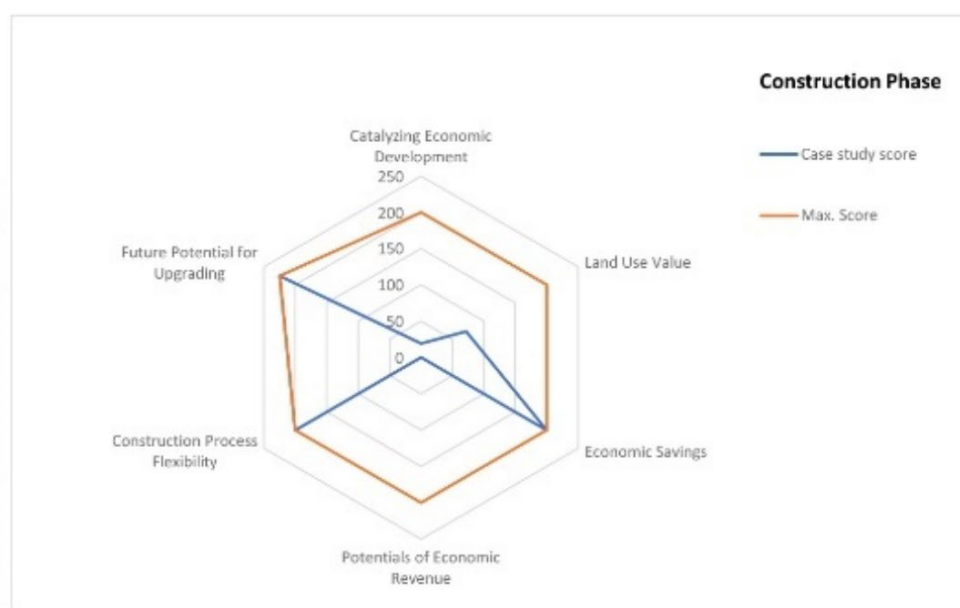
6.7.5. Economical -Technical Impact Assessment Chart

Fig. (183) Wetland Park's Economical -Technical Impact Assessment analysis, Source: Author

Project Title: 10th Ramadan Wetland
 Project Type: Constructed Wetland Park
 Location: 10th City, Cairo Governorate, Egypt, 30°20'17.9"N 31°47'19.2"E
 Climatic Zone: Arid Climate, BWh
 Hardiness Zone: 10
 Assessment Author: Aya ElMeligy

| | | | Construction Phase | | | | | | | | | | | |
|-----------------------------------|------------------|----------------------------------|--------------------|-------------------|------------------|---------------|----------------------------------|------------------|------------------|------------|-----|----------------------------|-----------|------------------------|
| Nr. | Category | Impact Factor | M Magnitude | S Significance | P Probability | D Duration | IV= Impact Value Relevance | Factor Weight | Case study score | Max. Score | % | Total Category Score | Max Score | Percentage Achieved |
| 25 | Economic Values | Catalyzing Economic Development | 2 | 3 | 4 | 1 | 24 | 0.8 | 19.2 | 200 | 9.6 | 291.2 | 800 | 36.40% |
| 26 | | Land Use Value | 3 | 3 | 5 | 2 | 90 | 0.8 | 72 | 200 | 36 | | | |
| 27 | | Economic Savings | 5 | 5 | 5 | 2 | 250 | 0.8 | 200 | 200 | 100 | | | |
| 28 | | Potentials of Economic Revenue | 0 | 2 | 5 | 2 | 0 | 0.8 | 0 | 200 | 0 | | | |
| 29 | Technical Values | Construction Process Flexibility | 5 | 5 | 5 | 2 | 250 | 0.8 | 200 | 200 | 100 | 425 | 425 | 100.00% |
| 30 | | Future Potential for Upgrading | 5 | 5 | 5 | 2 | 250 | 0.9 | 225 | 225 | 100 | | | |
| Total Economical -Technical Value | | | | | | | | | 716 | 1225 | | 716 | 1225 | 58.47% |

| | | | Operation Phase | | | | | | | | | | | | | |
|-----------------------------------|-------------------------------------|---|---------------------------------|-------------------|------------------|---------------|----------------------------------|------------------|------------------|------------|-----|----------------------------|-----------|------------------------|---------|--------|
| Nr. | Category | Impact Factor | M Magnitude | S Significance | P Probability | D Duration | IV= Impact Value relevance | Factor Weight | Case study score | Max. Score | % | Total Category Score | Max Score | Percentage Achieved | | |
| 25 | Economic - Technical Impact Factors | Economic Values | Catalyzing Economic Development | | 3 | 5 | 4 | 2 | 120 | 0.8 | 96 | 200 | 48 | 536 | 800 | 67.00% |
| 26 | | | Land Use Value | | 3 | 5 | 5 | 2 | 150 | 0.8 | 120 | 200 | 60 | | | |
| 27 | | | Economic Savings | | 5 | 5 | 5 | 2 | 250 | 0.8 | 200 | 200 | 100 | | | |
| 28 | | | Potentials of Economic Revenue | | 3 | 5 | 5 | 2 | 150 | 0.8 | 120 | 200 | 60 | | | |
| 29 | Technical Values | Operation and Maintenance Process Flexibility | | 5 | 5 | 5 | 2 | 250 | 0.8 | 200 | 200 | 100 | 425 | 425 | 100.00% | |
| 30 | | Future Potential for Upgrading | | 5 | 5 | 5 | 2 | 250 | 0.9 | 225 | 225 | 100 | | | | |
| Total Economical -Technical Value | | | | | | | | | 961 | 1225 | | 961 | 1225 | 78.45% | | |



6.8. Conclusion and Results

Since the project is still under construction and no accurate measures for the various impacts, the following points are recommended after the operation of the park:

1. **Air Quality** measurement study is recommended after 2 years of the plantation of the park, which would generate a more accurate results, since the benefits improve with canopy size.
2. For accurate assessment of the **Urban Micro-Climate** impacts and for a better comprehensive analysis of temperature impacts, long monitoring period and more frequent measurements is advised. Further study is recommended in 2 years after plantation, which would create a more accurate results, since the benefits improve with canopy size and the density of the vegetation cover.
3. Due to absence of information of relevant data of Egypt and some native species in the i-Tree application and the use of similar location and species, it is advisable to measure the **carbon footprint, storage and sequestration** of the park according to the DBH and accurate measures and monitoring of the park after every 2 years to get accurate results.
4. For a better comparative analysis of **energy savings** further study is recommended in 2 years after operation, which would create more accurate results and comparison of the utility bills to measure the energy savings, energy production once the Biogas and solar panels are implemented in the project.
5. The implementation of the plans for the **measurement regulators** for energy consumption and irrigation is very much advised to be implemented for the continuous monitoring of the park's performance and the quick development of mitigation methods and corrective actions.
6. For a better comprehensive analysis of **waste management**, cost material savings and materials impact on temperature, ground water refill and decrease in heat island effects, monitoring and further study is recommended after operation for more accurate results.
7. **Organic wastes reuse** calculations should be studied for accurate calculations once information is available from the hydrology team, and once the precise data of the amount of vegetation in the water path is available, further studies is recommended after the operation of the park and every 6 months.
8. For the improvement in **soil quality** and reduction in erosion, it is recommended to perform another study after 2 years of the plantation of the park, for a more accurate results of soil fertility and upgraded percentage.
9. Vegetation structure, DBH, height and depth of species is advised regularly for the assessment of the **flora species** and their contribution in the improvement of the environmental values. Studies for the introduced species and their performance in the location is also recommended for the accurate benefits in the location.
10. For assessing the **vegetation's benefits for Ecology and Ecosystem**, the suggested equations could be used according to the available information for each individual park. (Please check Chapter 2; 2.5)
11. Intensive observation of the **fauna enrichment** in the project is recommended to quantify the numbers of species that are introduced as a result of the introduction of various flora species and the creation of the waterway.
12. Further studies are recommended for **reused water** amounts in the different suggested plans of reuse. In addition to the monitoring of the annual amount of rainwater catchment and the potential income from selling excess water to the municipality.
13. Assessment of the **water quality** of treated water is recommended regularly for the improvement of the construct

Chapter 7: Conclusion

7.1. Findings

Through the application of the proposed assessment tool and since the project is in arid climate with scarcity of water and vegetation, it was clear that projects in similar climatic conditions would have low sustainability achievement during construction phase since some factors would still be under construction. For example, no achievement would be achieved in the water quality and consequently in the water reuse, since the water path would still be under construction. While similar projects in other climatic regions could have better results since water already exists and could have some improvements even in the construction phase. Similarly, the pre-existence of vegetation in the site would achieve better values in the improvement of all climatic factors. On the other hand, projects in arid climate would achieve better sustainability results during operation phase, as they will have a significance improvement on the environment due to the enriching of the hot desertic locations with vegetation cover, thus, tremendously improving the climatic factors; reducing temperature, urban micro-climate and pollution while improving air quality. After the creation of the water path and start of the water purification and thus water reuse, better improvements could be achieved in both factors.

7.2. Results

A questionnaire was used to determine the weights of the suggested impacts, as well as their relevance on the CWP's sustainability. The questionnaire was completed by 104 professionals from over 18 nations across the world to arrive at an indicative global evaluation tool. The results of the questionnaire analysis and weight calculations revealed that all the proposed indicators were convenient, and each's relevance weight was calculated based on the importance assigned by participants. However, it was discovered that relative weights reveal that some indicators are more relevant than others, and that some indicators' relative weight varies depending on the project's phase. The findings also highlighted that the three sustainability pillars are vital to the evaluation process and should not be overlooked. Where the evaluation revealed the following importance percentages in achieving sustainability; Environmental Impacts 42.34%, Socio-Cultural Impacts 29.47%, and Economical-Technical Impacts 28.19%. These weights, as well as the impact's relative weights, have been progressively developed and documented in the suggested evaluation tool. Where the proposed CW parks' assessment index indicates the relative weight of each factor, impact, and phase for a precise and accurate assessment of park performance. Thus, the CWP Index is applicable to various parks in relation to their diverse types, conditions, characteristics, and phases. The impact's relative weights help assess the sustainability achievement of each category, each phase and the Park's overall sustainability achievement. With the implementation of the proposed CWP Index on a case study in Egypt, it was demonstrated the capability of the proposed tool to assess CWP Projects even while they are still under construction using the suggested methods, tools, equations, and applications to quantify the expected performance, in this case study the **i-Tree Eco v6** application was used. This helps assess park's sustainability performance at an early stage, to have a clear insight of the project's performance and suggestions for potential improvement and areas of concern and consequently applying mitigation measures to achieve better sustainability performance.

7.3. Limitations:

The proposed CWP Index is based on the assessor's appraisal, which requires him to quantify his own evaluation of the impacts' scoring in the rating system. It is crucial that the given values are based on facts as much as possible rather than the evaluator's personal opinion. A thorough understanding of the factor's performance is essential to analyze the sustainability impact of the CW Parks, therefore a set of measuring methods, equations, tools, and applications were proposed to select the best that suits each park's accessible data. This will aid the assessor in quantitatively calculating the score for each impact element based on the available data and in a methodical manner. (See points: 5.5 Methods of Measurements and 5.6 Tools for Indicators Measurements)

7.4. Recommendations

Constructed Wetland Park, CWP, can function as a catalyst project in the urban setting of both old and new cities, assisting in positive change and adaptation to environmental factors, as well as boosting the city's sustainability and resilience. Besides its crucial function in encouraging better social interaction and fostering a sense of communal belonging and security, it also has diverse economic benefits. The CWP projects could be implemented as low cost decentralized projects, hence, they could be applied in different scales; as domestic water treatment park in neighborhood, district's recreational park or large scale touristic park in big cities. The CW Parks are very effective regardless of the climatic conditions, they offer great opportunities for developing cities to ensure economic upgrading potentials. They have a great influence on hot arid climate cities, hence, it is recommended to be adapted in developing hot arid climate countries, like Egypt for their great role in enhancing sustainability and for upgrading communities as catalyst projects for economic, social and economic aspects' enhancement. Intensive observation of the park's performance is advised through continuous performance assessment and accurate data monitoring and analysis for upgrading the park's performance. Regular assessment of the **treated water quality** is recommended for applying improvement methods and mitigation to ensure future potential upgrading of the constructed wetland performance and the reduction of water evaporation through effective design criteria, especially in hot-arid climates to ensure the maximum water reuse. Regular maintenance, monitoring and periodic removal of wetland deposits, as well as the reintroduction of fresh substrates into the cells, are critical operations for extending the wetlands efficiency and increasing their lifespan, thus, ensuring its sustainability. CWPs, are prominent effective multifunctional parks that embraces nature-based approaches to mitigate negative environmental effects, supporting beneficial improvements and having a positive impact on the environment. They are catalyst projects that help cities in overcoming the consequences of the two major crises, climate change and water scarcity in addition to introducing more vegetation and enhancing biodiversity. The proposed assessment tool, CWP Index, is an applicable and easy to use assessment tool that helps in the evaluation of the CW park project's performance to reach an optimum and more feasible project that enhances the social, economic and environmental aspects to develop a sustainable city. CW has been effectively adopted as a natural water filtration technique and is extensively utilized as an environmental tool in many cities across the world, but are not very widespread in developing nations, despite their excellent applicability since they achieve various benefits like boosting biodiversity, habitats, water treatment, and reducing air pollution. As a result, more awareness and exposure regarding it should be extended in developing nations, and appropriate incentives should be provided. Constructed wetlands technology is often recognized as a low-cost, simple-to-operate, and practical alternative to traditional wastewater treatment systems. However, scarcity of technicians and professionals in these sectors is a barrier, so it is crucial to qualify and train more specialists. To stimulate the adoption of these projects in developing countries, policies, regulations, and privileges should be established.

7.5. Conclusion

Constructed wetlands all over the world have proven to have obvious positive impacts on different aspects of the environment as well as contributing on the reuse of wastewater to address the increasing water scarcity in many countries. CW helps mitigating the climate change through various approaches and contributing to better environmental measures. CW Parks is an approach to create multifunctional projects which not only support the environmental aspects but rather combine other main pillars of sustainability; the socio-cultural, represented in offering recreational activities, social values and community engagement, and the economic factors, represented in offering potentials for economic revenues, economic savings and increasing land-use value. CWP encompasses several unique impacts and factors affecting sustainability, it requires having a unique specific designed CWP assessment tool that can efficiently target those various impacts as well as fitting the various projects in relevance to their diverse approaches, types, circumstances and characteristics. The proposed CWP Index is an easy and specific assessment tool for constructed wetland park performance that considers the main three categories of sustainability, each according to its relevance importance weight based on the results of a questionnaire with the participation of professionals on various related fields from all over the world. The proposed CWP Index evaluate each impact according to its importance weight as well as assessing the total sustainability achievement of the park through the relevance value of the project's phases' sustainability achievement. The proposed CWP Index is an easy to apply tool that can even assess projects under construction for expected sustainability performance evaluation and offer a summary of environmental impact assessment reports for better evaluation and assessment of the project's improvements chances in early stages and to identify weakness and strength impacts on environment to apply suitable mitigation measures once needed through a set of quantitative matrices and easy to understand visual charts.

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A 21st Century Research District for ASU /image courtesy Sasaki
Honor Award for Analysis and Planning category: Sasaki Associates for the A 21st Century Research District for ASU in Mesa, Arizona

9. Appendices

Appendix (1) Questionnaire's questions and format



Constructed Wetland Parks Sustainability Assessment

Dear participants,
Thank you for your time to participate in the questionnaire.
This questionnaire is a part of a Master's Thesis and a scientific research paper that focus on the development of a conceptual framework for assessment of Constructed Wetland Parks' performance as a multifunctional sustainable landscape project.

Constructed wetlands are engineered water treatment systems that employ the natural filtration properties of certain plants, soil particles and gravel.
Constructed wetland parks are nature-based, multifunction landscape projects that manage various ecosystem functions. The proposed indicator sets aim to assess the performance of CW parks projects in terms of their contribution to sustainability. Please determine the relative importance of indicators in order to define their weights in achieving sustainability goals and targets in both construction and operation phases. Please also evaluate the weights of the 3 proposed indicators categories.

The results will be used only for the academic purpose mentioned



The expected time of participation is about 8 minutes, we sincerely appreciate your valuable time

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Constructed Wetland Parks Sustainability Assessment

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Personal profile

Please identify your professional sector(s) 1 point

- ☐ Academic staff and reserachers
- ☐ Agriculture
- ☐ Architecture / Landscape / urban planning
- ☐ Civil / Infrastructure engineering
- ☐ Local municipality
- ☐ Project Management
- ☐ Civil / Infrastructure engineering
- ☐ Other: _____

Please identify the main area (s) of focus in your work? (Select all applicable areas)

- ☐ Biodiversity Enhancement
- ☐ Climate change mitigation
- ☐ Ecology
- ☐ Energy Conservation
- ☐ Green & blue Infrastructure / Nature-based solutions
- ☐ Human wellbeing / Quality of life
- ☐ Landscape / Agronomy
- ☐ Pollution / Air quality
- ☐ Resource (Materials) management
- ☐ Water quality
- ☐ Other: _____

Nationality



Your answer _____

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Constructed Wetland Parks Sustainability Assessment

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Weighting assessment categories of sustainability of constructed wetland parks

Please distribute the given 10 points among the 3 assessment categories according to their relative importance to sustainability of constructed wetland parks
Please note that the summation of points in the 3 categories is 10 points

Environmental Impacts (0-10) points

Your answer _____

Socio-cultural Impacts (0-10) points

Your answer _____

Economical - Technical Impacts (0-10) points

Your answer _____

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Constructed Wetland Parks Sustainability Assessment

Weighting socio-cultural indicators of constructed wetland parks

Based on a 5-point scale, please rate the following socio-cultural indicators according to their relative importance to the sustainability assessment of constructed wetland projects

Community size served by the project

1 2 3 4 5

☐ ☐ ☐ ☐ ☐

Community awareness of the project main functions

1 2 3 4 5

☐ ☐ ☐ ☐ ☐

Community acceptance of the project during construction and operation phases

1 2 3 4 5

Least important ☐ ☐ ☐ ☐ ☐ Most important

Education / Training during construction and operation phases

1 2 3 4 5

Least important ☐ ☐ ☐ ☐ ☐ Most important

Public participation during construction and operation phases

1 2 3 4 5

Least important ☐ ☐ ☐ ☐ ☐ Most important

Increased recreational & social activities

1 2 3 4 5

Least important ☐ ☐ ☐ ☐ ☐ Most important

Added social & connectivity values during construction & operation phases

1 2 3 4 5

Least important ☐ ☐ ☐ ☐ ☐ Most important

Visual / Aesthetic values of the project

1 2 3 4 5

Least important ☐ ☐ ☐ ☐ ☐ Most important

Odor reduction efficiency during operation phase

1 2 3 4 5

Least important ☐ ☐ ☐ ☐ ☐ Most important

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Constructed Wetland Parks Sustainability Assessment

Weighting economic - technical indicators of constructed wetland parks

Based on a 5-point scale, please rate the following economic and technical indicators according to their relative importance to the sustainability assessment of constructed wetland projects

Catalyzing economic development

1 2 3 4 5

Least important ☐ ☐ ☐ ☐ ☐ Most important

Land use value

1 2 3 4 5

Least important ☐ ☐ ☐ ☐ ☐ Most important

Economic savings

1 2 3 4 5

Least important ☐ ☐ ☐ ☐ ☐ Most important

Potentials of economic revenue

1 2 3 4 5

Least important ☐ ☐ ☐ ☐ ☐ Most important

Construction process flexibility

1 2 3 4 5

Least important ☐ ☐ ☐ ☐ ☐ Most important

Operation and maintenance process flexibility

1 2 3 4 5

Least important ☐ ☐ ☐ ☐ ☐ Most important

Potential for future upgrading of project

1 2 3 4 5

Least important ☐ ☐ ☐ ☐ ☐ Most important

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Constructed Wetland Parks Sustainability Assessment

Weighting environmental indicators of constructed wetland parks

Based on a 5- point scale, please rate the following environmental indicators according to their relative importance to the sustainability assessment of constructed wetland projects in construction phase and operation phase

Air quality during construction phase

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Air quality during operation phase

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Urban micro-climate during construction phase

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Urban micro-climate during operation phase

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Carbon footprint during construction phase

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Carbon footprint during operation phase

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Noise during construction phase

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Noise during operation phase

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Energy consumption during construction phase

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Energy consumption during operation phase

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Material use during construction phase

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Material use during operation phase

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Solid / Liquid wastes during construction phase

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Solid / Liquid wastes during operation phase

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Soil quality

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Flora enhancement

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Fauna enhancement

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

Water quality during operation phase

Least important 1 2 3 4 5 Most important

☐ ☐ ☐ ☐ ☐

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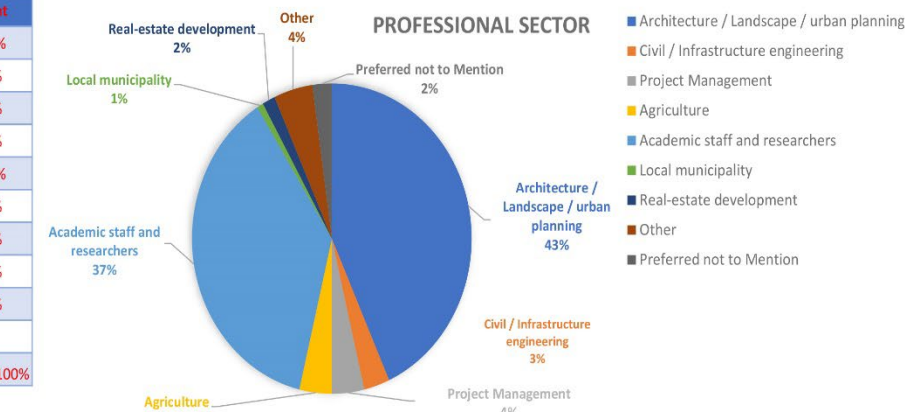
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Appendix (2) Analysis of question results

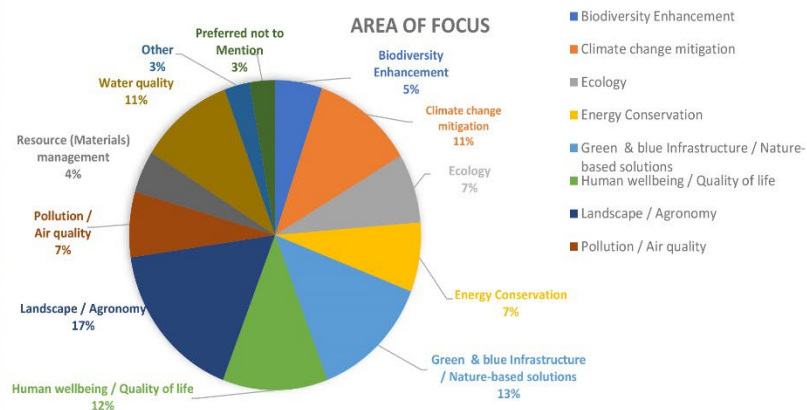
First Section: Participant's Profile:

| Q1_Professional Sector | Quantity | Percent |
|---|----------|---------|
| Architecture / Landscape / urban planning | 58 | 43.28% |
| Civil / Infrastructure engineering | 4 | 2.99% |
| Project Management | 5 | 3.73% |
| Agriculture | 5 | 3.73% |
| Academic staff and researchers | 50 | 37.31% |
| Local municipality | 1 | 0.75% |
| Real-estate development | 2 | 1.49% |
| Other | 6 | 4.48% |
| Preferred not to Mention | 3 | 2.24% |
| Total | 134 | 100% |



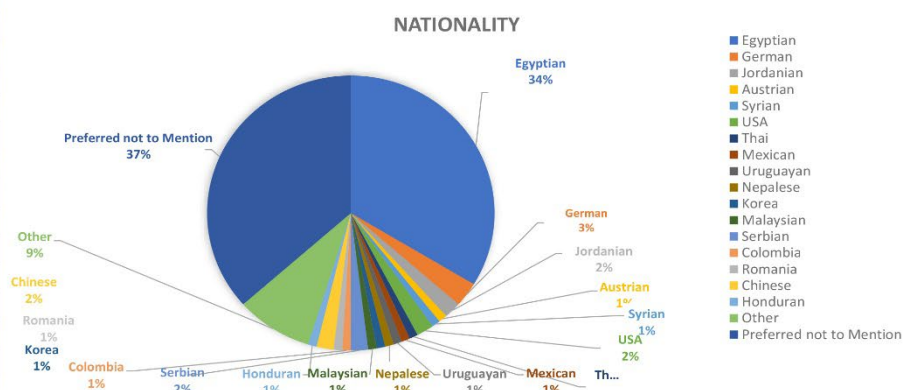
Q1_Please identify your professional sector(s)

| Q2_Area of Focus | Quantity | Percent |
|--|----------|---------|
| Biodiversity Enhancement | 13 | 5.22% |
| Climate change mitigation | 28 | 11.24% |
| Ecology | 18 | 7.23% |
| Energy Conservation | 18 | 7.23% |
| Green & blue Infrastructure / Nature-based solutions | 33 | 13.25% |
| Human wellbeing / Quality of life | 29 | 11.65% |
| Landscape / Agronomy | 42 | 16.87% |
| Pollution / Air quality | 17 | 6.83% |
| Resource (Materials) management | 11 | 4.42% |
| Water quality | 26 | 10.44% |
| Other | 7 | 2.81% |
| Preferred not to Mention | 7 | 2.81% |
| Total | 249 | 100% |



Q2_Please identify the main area (s) of focus in your work? (Select all applicable areas)

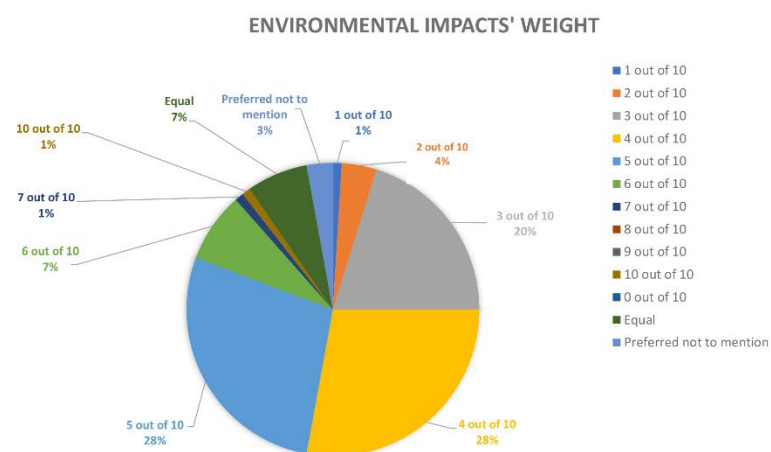
| Q3_Nationality | Respondents | Percent |
|--------------------------|-------------|---------|
| Egyptian | 35 | 33.65% |
| German | 3 | 2.88% |
| Jordanian | 2 | 1.92% |
| Austrian | 1 | 0.96% |
| Syrian | 1 | 0.96% |
| USA | 2 | 1.92% |
| Thai | 1 | 0.96% |
| Mexican | 1 | 0.96% |
| Uruguayan | 1 | 0.96% |
| Nepalese | 1 | 0.96% |
| Korea | 1 | 0.96% |
| Malaysian | 1 | 0.96% |
| Serbian | 2 | 1.92% |
| Colombia | 1 | 0.96% |
| Romania | 1 | 0.96% |
| Chinese | 2 | 1.92% |
| Honduran | 1 | 0.96% |
| Other | 9 | 8.65% |
| Preferred not to Mention | 38 | 36.54% |
| Total | 104 | 100% |



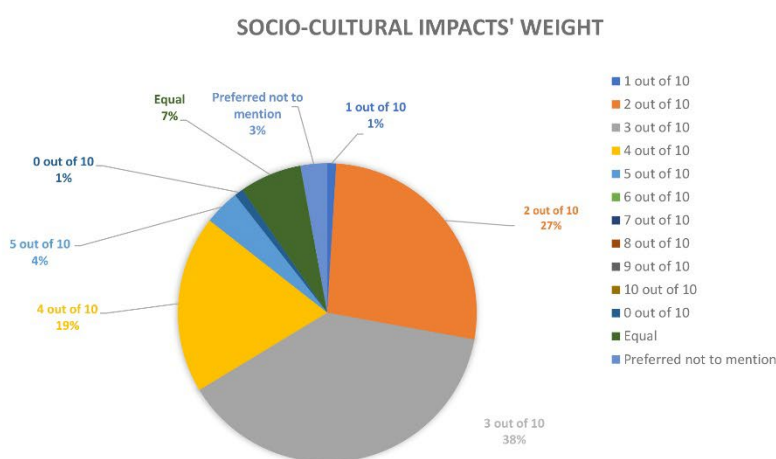
Q3_Nationality

Second Section: Determination of the weights for the main categories of CW Parks sustainability assessment

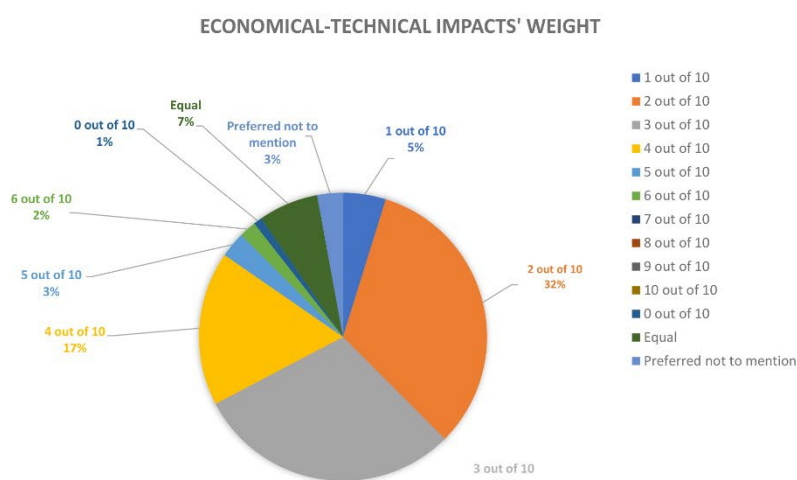
| Q4_Environmental Impacts (0-10) points | Respondents | Percent | Score |
|--|-------------|---------|----------|
| 1 out of 10 | 1 | 0.96% | 0.1 |
| 2 out of 10 | 4 | 3.85% | 0.2 |
| 3 out of 10 | 21 | 20.19% | 0.3 |
| 4 out of 10 | 29 | 27.88% | 0.4 |
| 5 out of 10 | 29 | 27.88% | 0.5 |
| 6 out of 10 | 8 | 7.69% | 0.6 |
| 7 out of 10 | 1 | 0.96% | 0.7 |
| 8 out of 10 | 0 | 0% | 0.8 |
| 9 out of 10 | 0 | 0% | 0.9 |
| 10 out of 10 | 1 | 0.01 | 1.0 |
| 0 out of 10 | 0 | 0.00% | 0 |
| Equal | 7 | 6.73% | |
| Preferred not to mention | 3 | 2.88% | |
| Total | 104 | 100.00% | 39.8 |
| WAI = $\frac{\sum f_i w_i}{\sum f_i}$ | 39.8 | 42.34% | 94 |
| | 94 | 42.34% | 0.423404 |



| Q5_Socio-Cultural Impacts (0-10) points | Respondents | Percent | Score |
|---|-------------|---------|----------|
| 1 out of 10 | 1 | 0.96% | 0.1 |
| 2 out of 10 | 28 | 26.92% | 0.2 |
| 3 out of 10 | 40 | 38.46% | 0.3 |
| 4 out of 10 | 20 | 19.23% | 0.4 |
| 5 out of 10 | 4 | 3.85% | 0.5 |
| 6 out of 10 | 0 | 0.00% | 0.6 |
| 7 out of 10 | 0 | 0.00% | 0.7 |
| 8 out of 10 | 0 | 0% | 0.8 |
| 9 out of 10 | 0 | 0.00% | 0.9 |
| 10 out of 10 | 0 | 0.00 | 1.0 |
| 0 out of 10 | 1 | 0.96% | 0 |
| Equal | 7 | 6.73% | |
| Preferred not to mention | 3 | 2.88% | |
| Total | 104 | 100.00% | 27.7 |
| WAI = $\frac{\sum f_i w_i}{\sum f_i}$ | 27.7 | 29.47% | 94 |
| | 94 | 29.47% | 0.294681 |



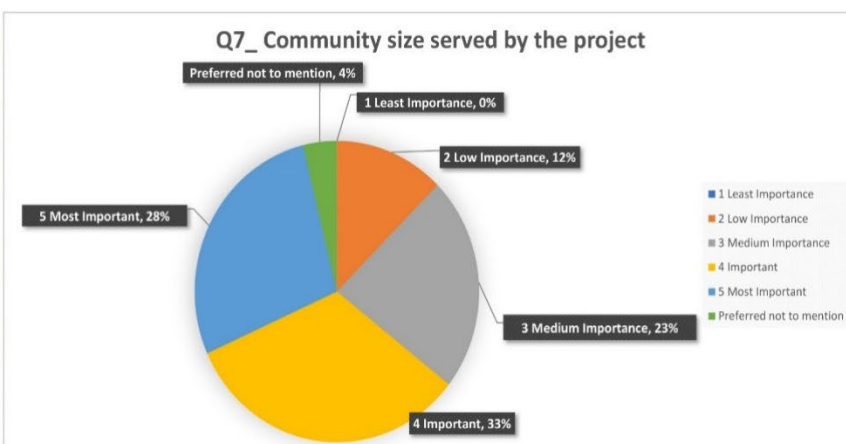
| Q6_Economical - Technical Impacts (0-10) points | Respondents | Percent | Score |
|---|-------------|---------|----------|
| 1 out of 10 | 5 | 4.81% | 0.1 |
| 2 out of 10 | 34 | 32.69% | 0.2 |
| 3 out of 10 | 31 | 29.81% | 0.3 |
| 4 out of 10 | 18 | 17.31% | 0.4 |
| 5 out of 10 | 3 | 2.88% | 0.5 |
| 6 out of 10 | 2 | 1.92% | 0.6 |
| 7 out of 10 | 0 | 0.00% | 0.7 |
| 8 out of 10 | 0 | 0% | 0.8 |
| 9 out of 10 | 0 | 0.00% | 0.9 |
| 10 out of 10 | 0 | 0.00 | 1.0 |
| 0 out of 10 | 1 | 0.96% | 0 |
| Equal | 7 | 6.73% | |
| Preferred not to mention | 3 | 2.88% | |
| Total | 104 | 100.00% | 26.5 |
| WAI = $\frac{\sum f_i w_i}{\sum f_i}$ | 26.5 | 28.19% | 94 |
| | 94 | 28.19% | 0.281915 |



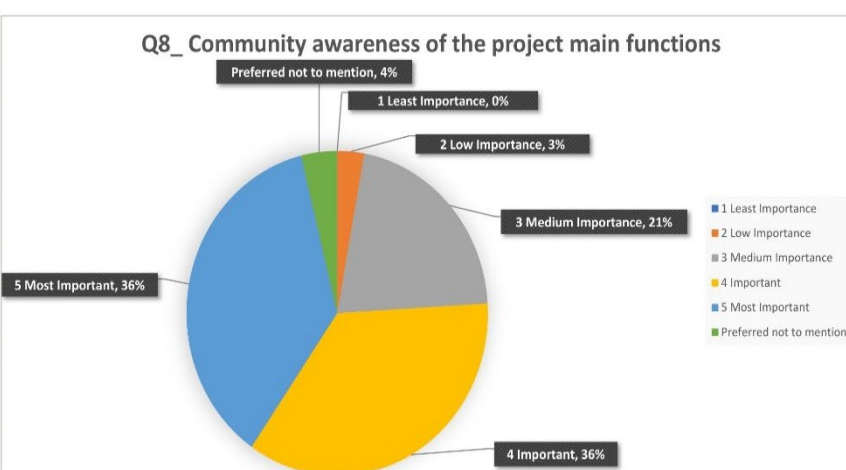
Third Section: Individual Indicator Weights identification

Part 1: Weighting Socio - Cultural indicators of constructed wetland parks

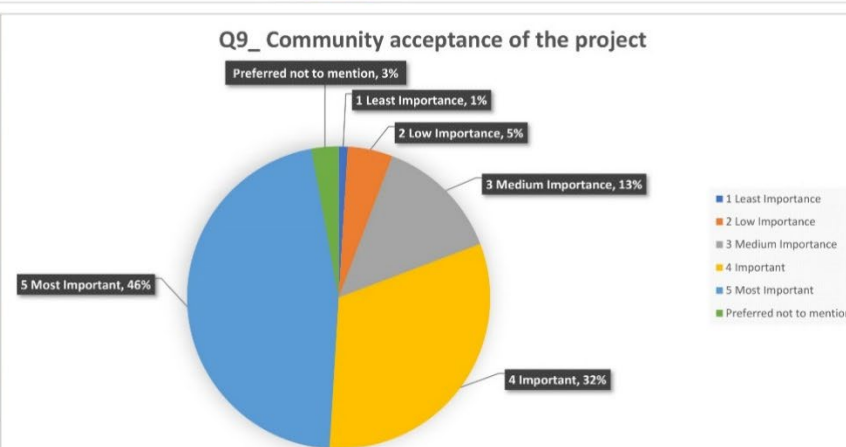
| Q7_ Community size served by the project | Respondents | Percent | Score |
|--|-------------|---------|-------|
| 1 Least Importance | 0 | 0.00% | 0.2 |
| 2 Low Importance | 13 | 12.50% | 0.4 |
| 3 Medium Importance | 24 | 23.08% | 0.6 |
| 4 Important | 34 | 32.69% | 0.8 |
| 5 Most Important | 29 | 27.88% | 1 |
| Preferred not to mention | 4 | 3.85% | |
| Total | 104 | 100% | 75.8 |
| | 75.8 | 75.80% | 100 |
| $WAI = \frac{\sum f_i l_i}{\sum f_i}$ | 100 | 0.76 | 0.8 |



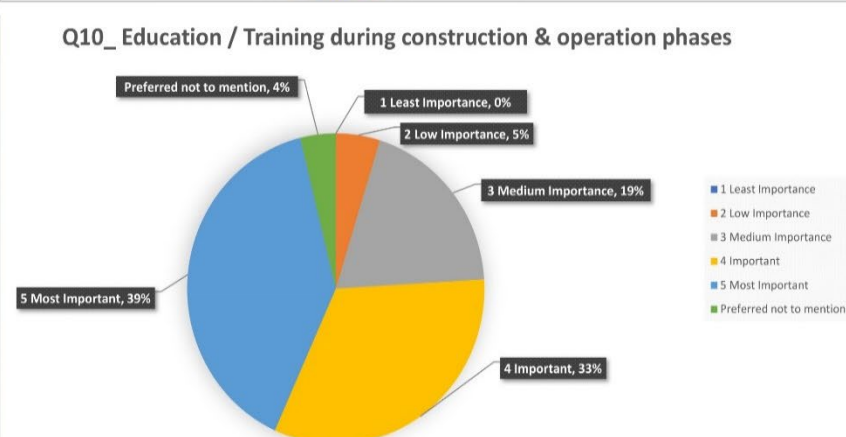
| Q8_ Community awareness of the project main functions | Respondents | Percent | Score |
|---|-------------|---------|-------|
| 1 Least Importance | 0 | 0.00% | 0.2 |
| 2 Low Importance | 3 | 2.88% | 0.4 |
| 3 Medium Importance | 22 | 21.15% | 0.6 |
| 4 Important | 37 | 35.58% | 0.8 |
| 5 Most Important | 38 | 36.54% | 1 |
| Preferred not to mention | 4 | 3.85% | |
| Total | 104 | 100% | 82 |
| | 82 | 82.00% | 100 |
| $WAI = \frac{\sum f_i l_i}{\sum f_i}$ | 100 | 0.82 | 0.8 |



| Q9_ Community acceptance of the project | Respondents | Percent | Score |
|---|-------------|---------|-------|
| 1 Least Importance | 1 | 0.96% | 0.2 |
| 2 Low Importance | 5 | 4.81% | 0.4 |
| 3 Medium Importance | 14 | 13.46% | 0.6 |
| 4 Important | 33 | 31.73% | 0.8 |
| 5 Most Important | 48 | 46.15% | 1 |
| Preferred not to mention | 3 | 2.88% | |
| Total | 104 | 100% | 85 |
| | 85 | 84.16% | 101 |
| $WAI = \frac{\sum f_i l_i}{\sum f_i}$ | 101 | 0.84 | 0.8 |

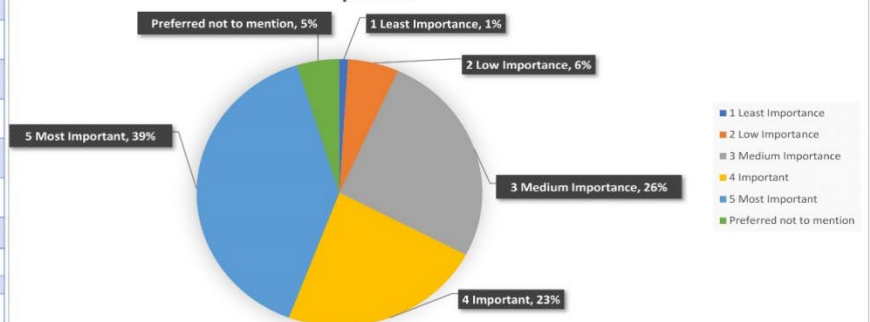


| Q10_ Education / Training during construction & operation phases | Respondents | Percent | Score |
|--|-------------|---------|-------|
| 1 Least Importance | 0 | 0.00% | 0.2 |
| 2 Low Importance | 5 | 4.81% | 0.4 |
| 3 Medium Importance | 20 | 19.23% | 0.6 |
| 4 Important | 34 | 32.69% | 0.8 |
| 5 Most Important | 41 | 39.42% | 1 |
| Preferred not to mention | 4 | 3.85% | |
| Total | 104 | 100% | 82.2 |
| | 82.2 | 82.20% | 100 |
| $WAI = \frac{\sum f_i l_i}{\sum f_i}$ | 100 | 0.82 | 0.8 |



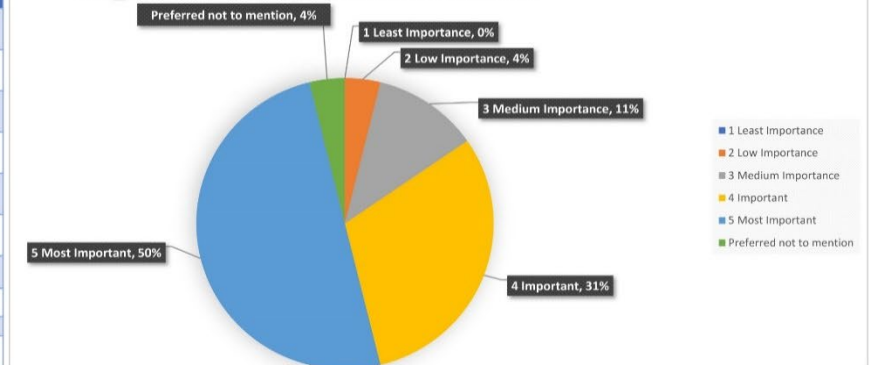
| Q11_ Public participation during construction and operation phases | Respondents | Percent | Score |
|--|-------------|---------|-------|
| 1 Least Importance | 1 | 0.96% | 0.2 |
| 2 Low Importance | 6 | 5.77% | 0.4 |
| 3 Medium Importance | 27 | 25.96% | 0.6 |
| 4 Important | 24 | 23.08% | 0.8 |
| 5 Most Important | 41 | 39.42% | 1 |
| Preferred not to mention | 5 | 4.81% | |
| Total | 104 | 100% | 79 |
| WAI = $\frac{\sum f_i w_i}{\sum f_i}$ | 79 | 79.80% | 99 |
| | 99 | 0.80 | 0.8 |

Q11_ Public participation during construction and operation phases



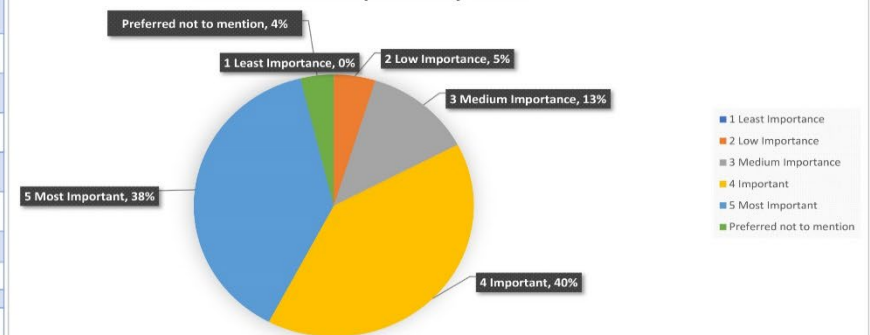
| Q12_ Increased recreational & social activities | Respondents | Percent | Score |
|---|-------------|---------|-------|
| 1 Least Importance | 0 | 0.00% | 0.2 |
| 2 Low Importance | 4 | 3.85% | 0.4 |
| 3 Medium Importance | 12 | 11.54% | 0.6 |
| 4 Important | 32 | 30.77% | 0.8 |
| 5 Most Important | 52 | 50.00% | 1 |
| Preferred not to mention | 4 | 3.85% | |
| Total | 104 | 100% | 86.4 |
| WAI = $\frac{\sum f_i w_i}{\sum f_i}$ | 86.4 | 86.40% | 100 |
| | 100 | 0.86 | 0.9 |

Q12_ Increased recreational & social activities



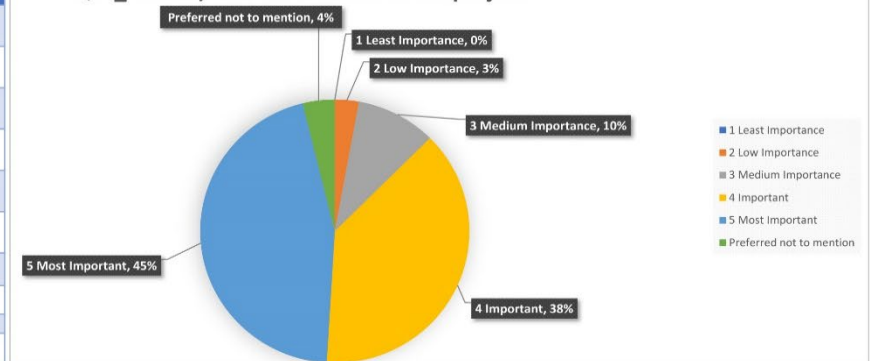
| Q13_ Added social, connectivity and safety values during construction & operation phases | Respondents | Percent | Score |
|--|-------------|---------|-------|
| 1 Least Importance | 0 | 0.00% | 0.2 |
| 2 Low Importance | 5 | 4.81% | 0.4 |
| 3 Medium Importance | 13 | 12.50% | 0.6 |
| 4 Important | 42 | 40.38% | 0.8 |
| 5 Most Important | 40 | 38.46% | 1 |
| Preferred not to mention | 4 | 3.85% | |
| Total | 104 | 100% | 83.4 |
| WAI = $\frac{\sum f_i w_i}{\sum f_i}$ | 83.4 | 83.40% | 100 |
| | 100 | 0.83 | 0.8 |

Q13_ Added social, connectivity and safety values during construction & operation phases



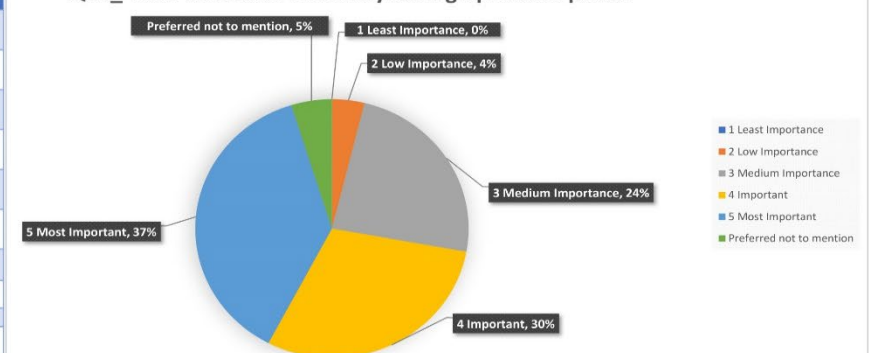
| Q14_ Visual / Aesthetic values of the project | Respondents | Percent | Score |
|---|-------------|---------|-------|
| 1 Least Importance | 0 | 0.00% | 0.2 |
| 2 Low Importance | 3 | 2.88% | 0.4 |
| 3 Medium Importance | 10 | 9.62% | 0.6 |
| 4 Important | 40 | 38.46% | 0.8 |
| 5 Most Important | 47 | 45.19% | 1 |
| Preferred not to mention | 4 | 3.85% | |
| Total | 104 | 100% | 86.2 |
| WAI = $\frac{\sum f_i w_i}{\sum f_i}$ | 86.2 | 86.20% | 100 |
| | 100 | 0.86 | 0.9 |

Q14_ Visual / Aesthetic values of the project



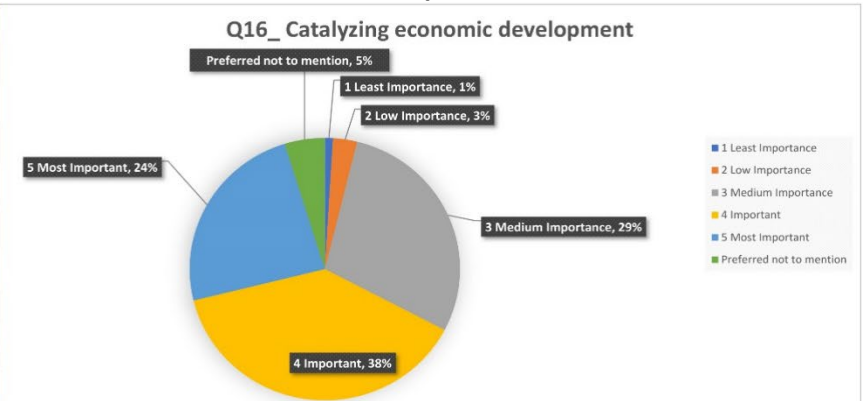
| Q15_ Odor reduction efficiency during operation phase | Respondents | Percent | Score |
|---|-------------|---------|-------|
| 1 Least Importance | 0 | 0.00% | 0.2 |
| 2 Low Importance | 4 | 3.85% | 0.4 |
| 3 Medium Importance | 25 | 24.04% | 0.6 |
| 4 Important | 31 | 29.81% | 0.8 |
| 5 Most Important | 39 | 37.50% | 1 |
| Preferred not to mention | 5 | 4.81% | |
| Total | 104 | 100% | 80.4 |
| WAI = $\frac{\sum f_i w_i}{\sum f_i}$ | 80.4 | 81.21% | 99 |
| | 99 | 0.81 | 0.8 |

Q15_ Odor reduction efficiency during operation phase

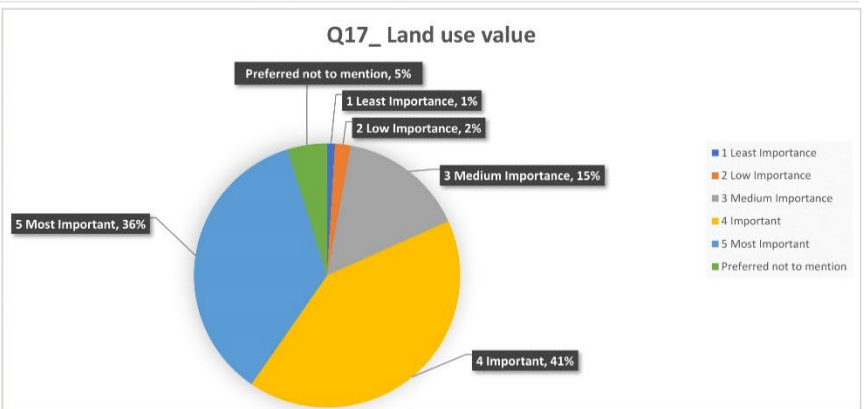


Part 2: Weighting Economic - Technical indicators of constructed wetland parks:

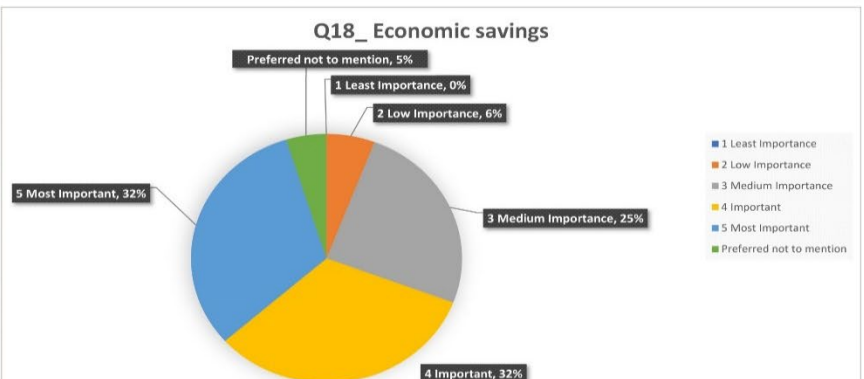
| Q16_ Catalyzing economic development | Respondents | Percent | Score |
|---------------------------------------|-------------|---------|-------|
| 1 Least Importance | 1 | 0.96% | 0.2 |
| 2 Low Importance | 3 | 2.88% | 0.4 |
| 3 Medium Importance | 30 | 28.85% | 0.6 |
| 4 Important | 40 | 38.46% | 0.8 |
| 5 Most Important | 25 | 24.04% | 1 |
| Preferred not to mention | 5 | 4.81% | |
| Total | 104 | 100% | 76.4 |
| | 76.4 | 77.17% | 99 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 99 | 0.77 | 0.8 |



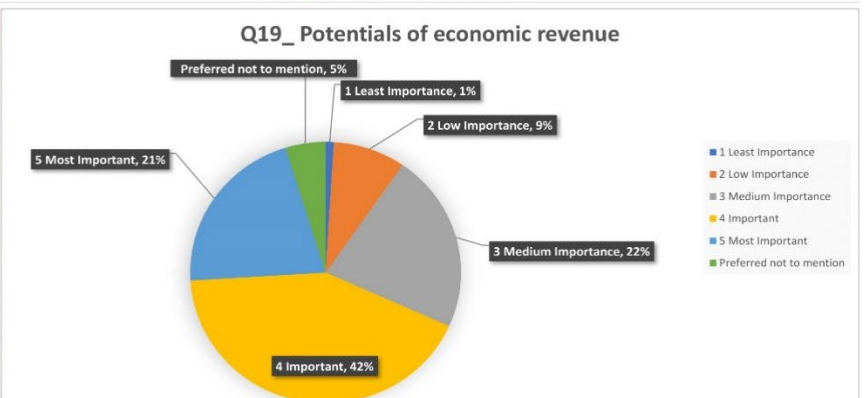
| Q17_ Land use value | Respondents | Percent | Score |
|---------------------------------------|-------------|---------|-------|
| 1 Least Importance | 1 | 0.96% | 0.2 |
| 2 Low Importance | 2 | 1.92% | 0.4 |
| 3 Medium Importance | 16 | 15.38% | 0.6 |
| 4 Important | 43 | 41.35% | 0.8 |
| 5 Most Important | 37 | 35.58% | 1 |
| Preferred not to mention | 5 | 4.81% | |
| Total | 104 | 100% | 82 |
| | 82 | 82.83% | 99 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 99 | 0.83 | 0.8 |



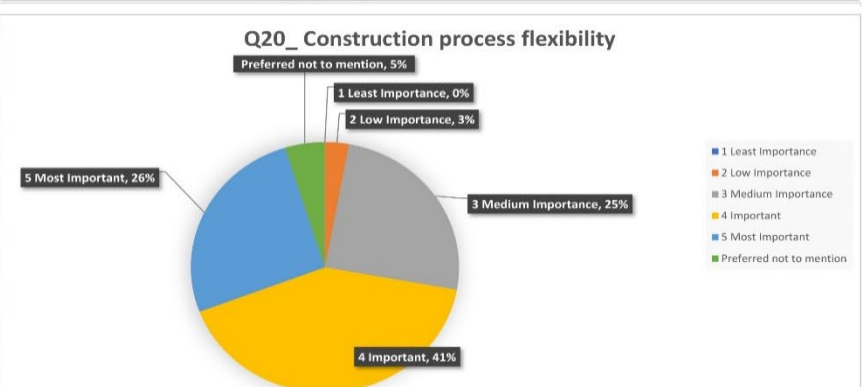
| Q18_ Economic savings | Respondents | Percent | Score |
|---------------------------------------|-------------|---------|-------|
| 1 Least Importance | 0 | 0.00% | 0.2 |
| 2 Low Importance | 6 | 5.77% | 0.4 |
| 3 Medium Importance | 26 | 25.00% | 0.6 |
| 4 Important | 34 | 32.69% | 0.8 |
| 5 Most Important | 33 | 31.73% | 1 |
| Preferred not to mention | 5 | 4.81% | |
| Total | 104 | 100% | 78.2 |
| | 78.2 | 78.99% | 99 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 99 | 0.79 | 0.8 |



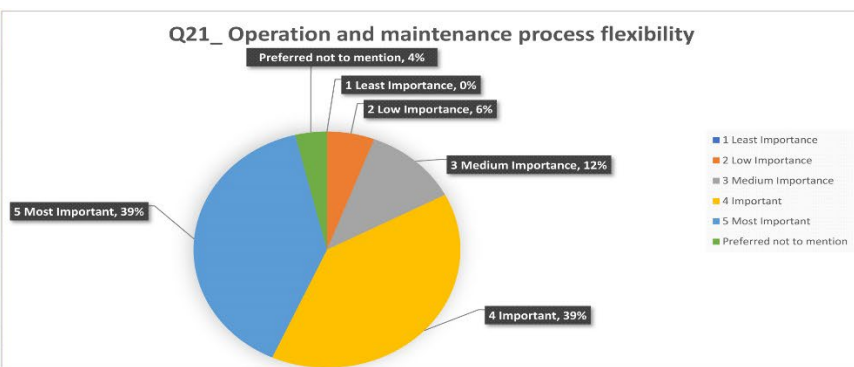
| Q19_ Potentials of economic revenue | Respondents | Percent | Score |
|---------------------------------------|-------------|---------|-------|
| 1 Least Importance | 1 | 0.96% | 0.2 |
| 2 Low Importance | 9 | 8.65% | 0.4 |
| 3 Medium Importance | 23 | 22.12% | 0.6 |
| 4 Important | 44 | 42.31% | 0.8 |
| 5 Most Important | 22 | 21.15% | 1 |
| Preferred not to mention | 5 | 4.81% | |
| Total | 104 | 100% | 74.8 |
| | 74.8 | 75.56% | 99 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 99 | 0.76 | 0.8 |



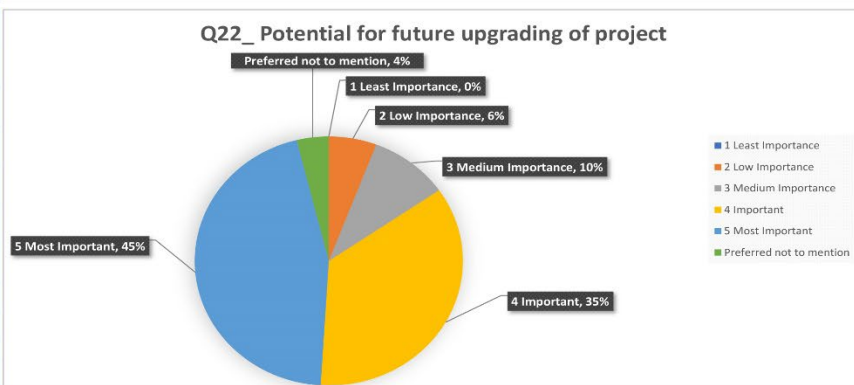
| Q20_ Construction process flexibility | Respondents | Percent | Score |
|---------------------------------------|-------------|---------|-------|
| 1 Least Importance | 0 | 0.00% | 0.2 |
| 2 Low Importance | 3 | 2.88% | 0.4 |
| 3 Medium Importance | 26 | 25.00% | 0.6 |
| 4 Important | 43 | 41.35% | 0.8 |
| 5 Most Important | 27 | 25.96% | 1 |
| Preferred not to mention | 5 | 4.81% | |
| Total | 104 | 100% | 78.2 |
| | 78.2 | 78.99% | 99 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 99 | 0.79 | 0.8 |



| Q21_ Operation and maintenance process flexibility | Respondents | Percent | Score |
|--|-------------|---------|-------|
| 1 Least Importance | 0 | 0.00% | 0.2 |
| 2 Low Importance | 6 | 5.77% | 0.4 |
| 3 Medium Importance | 12 | 11.54% | 0.6 |
| 4 Important | 41 | 39.42% | 0.8 |
| 5 Most Important | 41 | 39.42% | 1 |
| Preferred not to mention | 4 | 3.85% | |
| Total | 104 | 100% | 83.4 |
| | 83.4 | 83.40% | 100 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 100 | 0.83 | 0.8 |

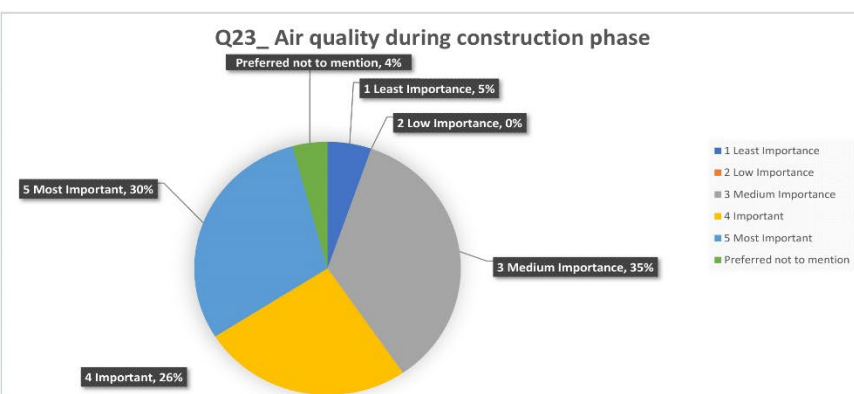


| Q22_ Potential for future upgrading of project | Respondents | Percent | Score |
|--|-------------|---------|-------|
| 1 Least Importance | 0 | 0.00% | 0.2 |
| 2 Low Importance | 6 | 5.77% | 0.4 |
| 3 Medium Importance | 10 | 9.62% | 0.6 |
| 4 Important | 37 | 35.58% | 0.8 |
| 5 Most Important | 47 | 45.19% | 1 |
| Preferred not to mention | 4 | 3.85% | |
| Total | 104 | 100% | 85 |
| | 85 | 85.00% | 100 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 100 | 0.85 | 0.9 |

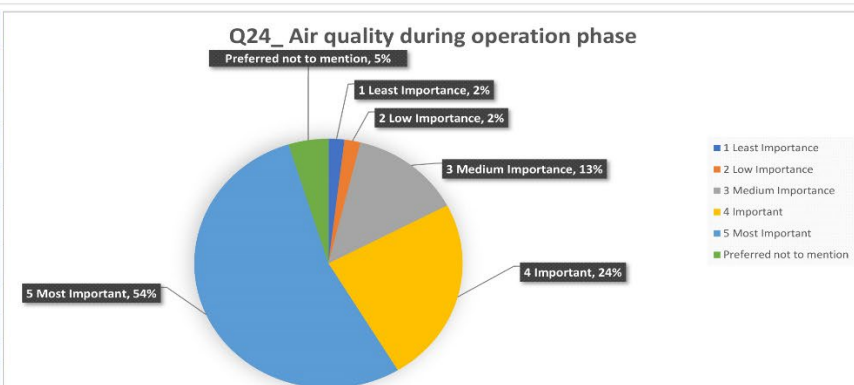


Part 3: Weighting Environmental indicators of constructed wetland parks:

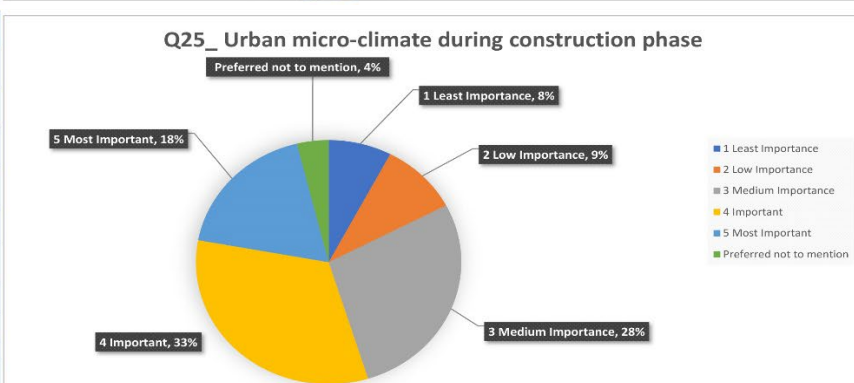
| Q23_ Air quality during construction phase | Respondents | Percent | Score |
|--|-------------|---------|-------|
| 1 Least Importance | 5 | 5.32% | 0.2 |
| 2 Low Importance | 0 | 0.00% | 0.4 |
| 3 Medium Importance | 33 | 35.11% | 0.6 |
| 4 Important | 24 | 25.53% | 0.8 |
| 5 Most Important | 28 | 29.79% | 1 |
| Preferred not to mention | 4 | 4.26% | |
| Total | 94 | 100% | 68 |
| | 68 | 75.56% | 90 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 90 | 0.76 | 0.8 |



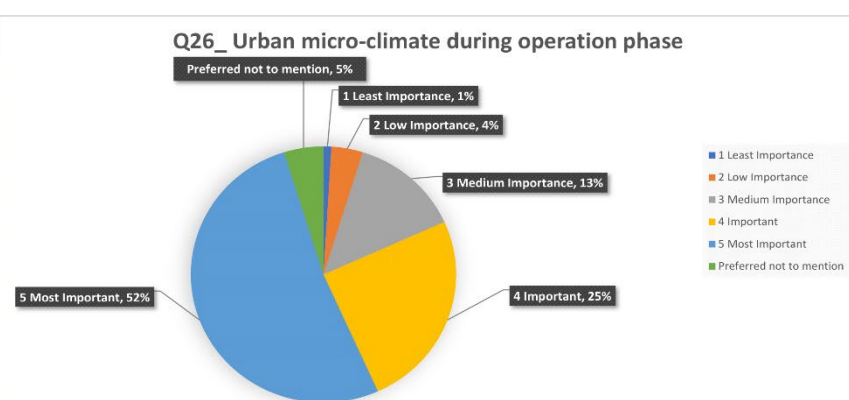
| Q24_ Air quality during operation phase | Respondents | Percent | Score |
|---|-------------|---------|-------|
| 1 Least Importance | 2 | 1.92% | 0.2 |
| 2 Low Importance | 2 | 1.92% | 0.4 |
| 3 Medium Importance | 14 | 13.46% | 0.6 |
| 4 Important | 25 | 24.04% | 0.8 |
| 5 Most Important | 56 | 53.85% | 1 |
| Preferred not to mention | 5 | 4.81% | |
| Total | 104 | 100% | 85.6 |
| | 85.6 | 86.46% | 99 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 99 | 0.86 | 0.9 |



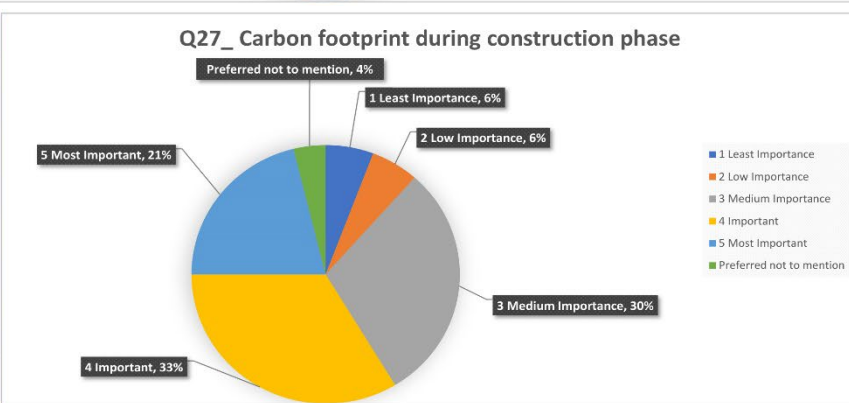
| Q25_ Urban micro-climate during construction phase | Respondents | Percent | Score |
|--|-------------|---------|-------|
| 1 Least Importance | 8 | 7.69% | 0.2 |
| 2 Low Importance | 10 | 9.62% | 0.4 |
| 3 Medium Importance | 29 | 27.88% | 0.6 |
| 4 Important | 34 | 32.69% | 0.8 |
| 5 Most Important | 19 | 18.27% | 1 |
| Preferred not to mention | 4 | 3.85% | |
| Total | 104 | 100% | 69.2 |
| | 69.2 | 69.20% | 100 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 100 | 0.69 | 0.7 |



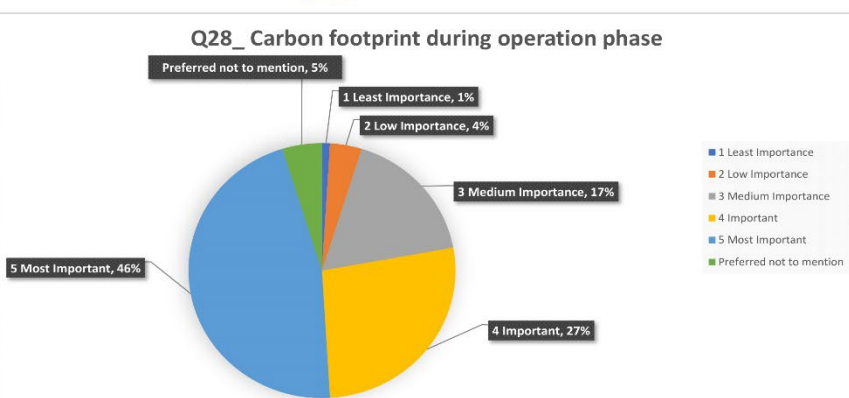
| Q26_ Urban micro-climate during operation phase | Respondents | Percent | Score |
|---|-------------|---------|-------|
| 1 Least Importance | 1 | 0.96% | 0.2 |
| 2 Low Importance | 4 | 3.85% | 0.4 |
| 3 Medium Importance | 14 | 13.46% | 0.6 |
| 4 Important | 26 | 25.00% | 0.8 |
| 5 Most Important | 54 | 51.92% | 1 |
| Preferred not to mention | 5 | 4.81% | |
| Total | 104 | 100% | 85 |
| | 85 | 85.86% | 99 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 99 | 0.86 | 0.9 |



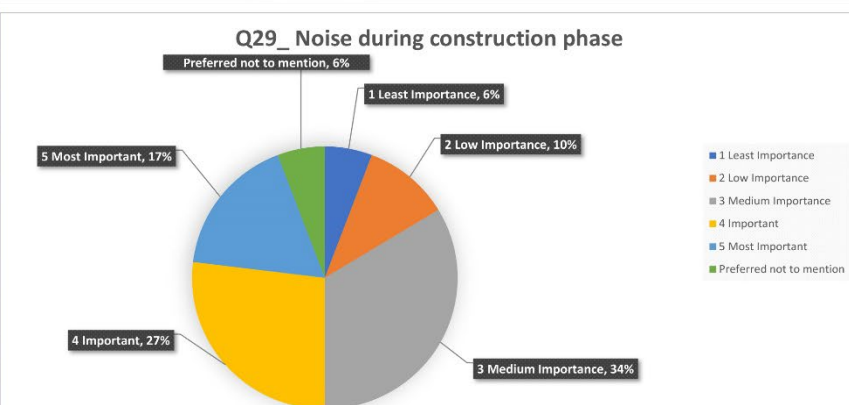
| Q27_ Carbon footprint during construction phase | Respondents | Percent | Score |
|---|-------------|---------|-------|
| 1 Least Importance | 6 | 5.77% | 0.2 |
| 2 Low Importance | 6 | 5.77% | 0.4 |
| 3 Medium Importance | 31 | 29.81% | 0.6 |
| 4 Important | 35 | 33.65% | 0.8 |
| 5 Most Important | 22 | 21.15% | 1 |
| Preferred not to mention | 4 | 3.85% | |
| Total | 104 | 100% | 72.2 |
| | 72.2 | 72.20% | 100 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 100 | 0.72 | 0.7 |



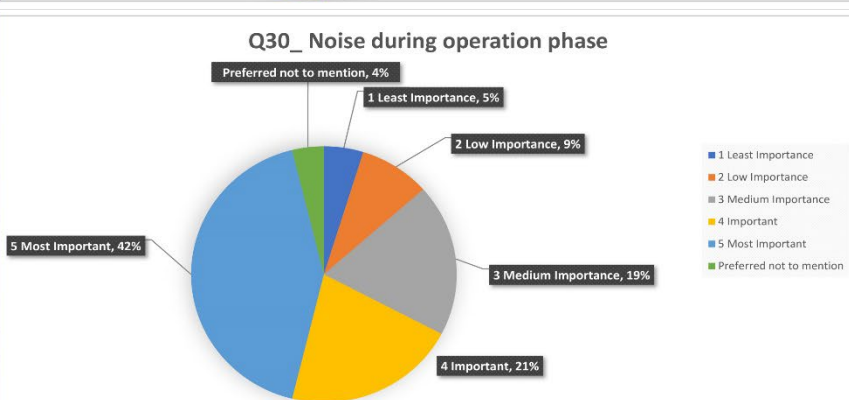
| Q28_ Carbon footprint during operation phase | Respondents | Percent | Score |
|--|-------------|---------|-------|
| 1 Least Importance | 1 | 0.96% | 0.2 |
| 2 Low Importance | 4 | 3.85% | 0.4 |
| 3 Medium Importance | 18 | 17.31% | 0.6 |
| 4 Important | 28 | 26.92% | 0.8 |
| 5 Most Important | 48 | 46.15% | 1 |
| Preferred not to mention | 5 | 4.81% | |
| Total | 104 | 100% | 83 |
| | 83 | 83.84% | 99 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 99 | 0.84 | 0.8 |



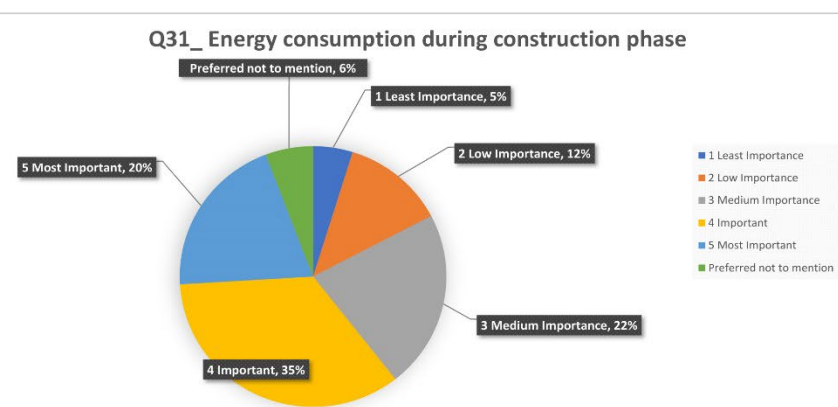
| Q29_ Noise during construction phase | Respondents | Percent | Score |
|---------------------------------------|-------------|---------|-------|
| 1 Least Importance | 6 | 5.77% | 0.2 |
| 2 Low Importance | 11 | 10.58% | 0.4 |
| 3 Medium Importance | 35 | 33.65% | 0.6 |
| 4 Important | 28 | 26.92% | 0.8 |
| 5 Most Important | 18 | 17.31% | 1 |
| Preferred not to mention | 6 | 5.77% | |
| Total | 104 | 100% | 67 |
| | 67 | 68.37% | 98 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 98 | 0.68 | 0.7 |



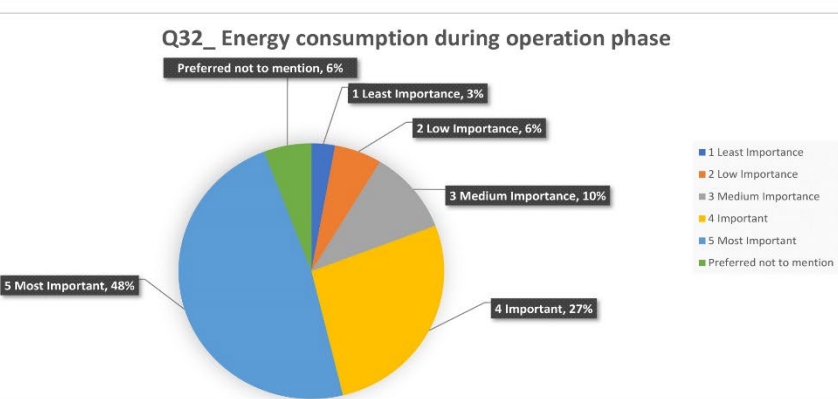
| Q30_ Noise during operation phase | Respondents | Percent | Score |
|---------------------------------------|-------------|---------|-------|
| 1 Least Importance | 5 | 4.81% | 0.2 |
| 2 Low Importance | 9 | 8.65% | 0.4 |
| 3 Medium Importance | 20 | 19.23% | 0.6 |
| 4 Important | 22 | 21.15% | 0.8 |
| 5 Most Important | 44 | 42.31% | 1 |
| Preferred not to mention | 4 | 3.85% | |
| Total | 104 | 100% | 78.2 |
| | 78.2 | 78.20% | 100 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 100 | 0.78 | 0.8 |



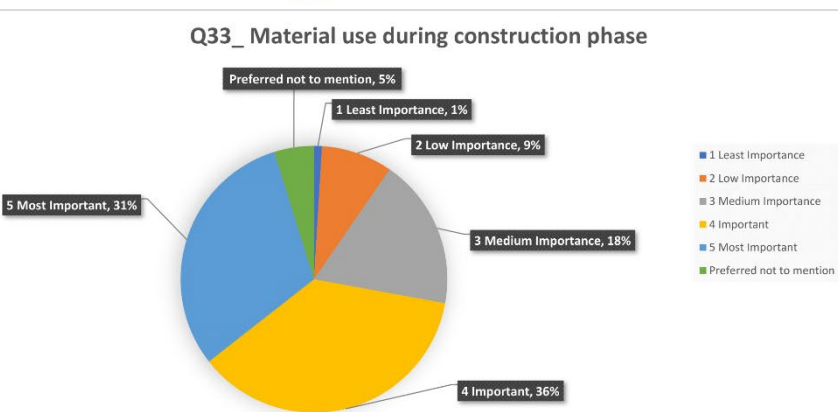
| Q31_ Energy consumption during construction phase | Respondents | Percent | Score |
|---|-------------|---------|-------|
| 1 Least Importance | 5 | 4.81% | 0.2 |
| 2 Low Importance | 13 | 12.50% | 0.4 |
| 3 Medium Importance | 23 | 22.12% | 0.6 |
| 4 Important | 36 | 34.62% | 0.8 |
| 5 Most Important | 21 | 20.19% | 1 |
| Preferred not to mention | 6 | 5.77% | |
| Total | 104 | 100% | 69.8 |
| | 69.8 | 71.22% | 98 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 98 | 0.71 | 0.7 |



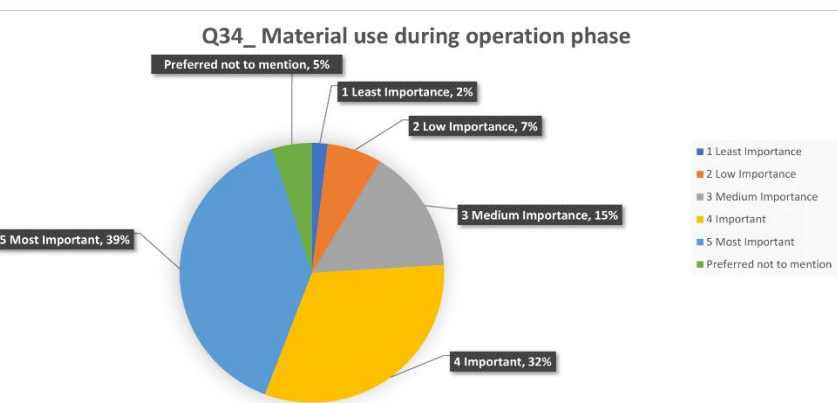
| Q32_ Energy consumption during operation phase | Respondents | Percent | Score |
|--|-------------|---------|-------|
| 1 Least Importance | 3 | 2.88% | 0.2 |
| 2 Low Importance | 6 | 5.77% | 0.4 |
| 3 Medium Importance | 11 | 10.58% | 0.6 |
| 4 Important | 28 | 26.92% | 0.8 |
| 5 Most Important | 50 | 48.08% | 1 |
| Preferred not to mention | 6 | 5.77% | |
| Total | 104 | 100% | 82 |
| | 82 | 83.67% | 98 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 98 | 0.84 | 0.8 |



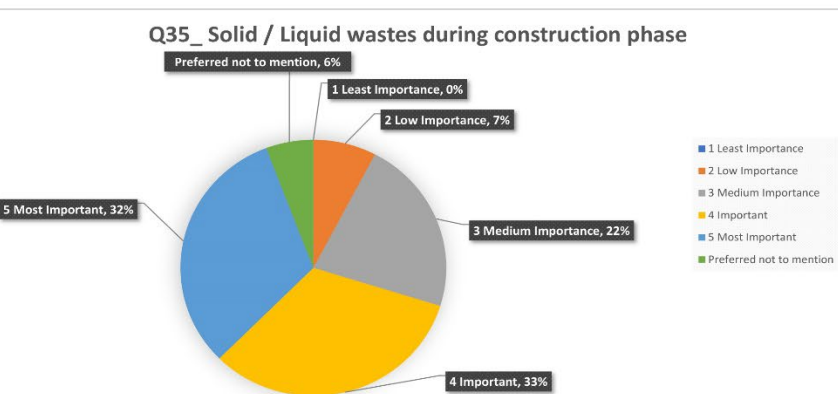
| Q33_ Material use during construction phase | Respondents | Percent | Score |
|---|-------------|---------|-------|
| 1 Least Importance | 1 | 0.96% | 0.2 |
| 2 Low Importance | 9 | 8.65% | 0.4 |
| 3 Medium Importance | 19 | 18.27% | 0.6 |
| 4 Important | 38 | 36.54% | 0.8 |
| 5 Most Important | 32 | 30.77% | 1 |
| Preferred not to mention | 5 | 4.81% | |
| Total | 104 | 100% | 77.6 |
| | 77.6 | 78.38% | 99 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 99 | 0.78 | 0.8 |



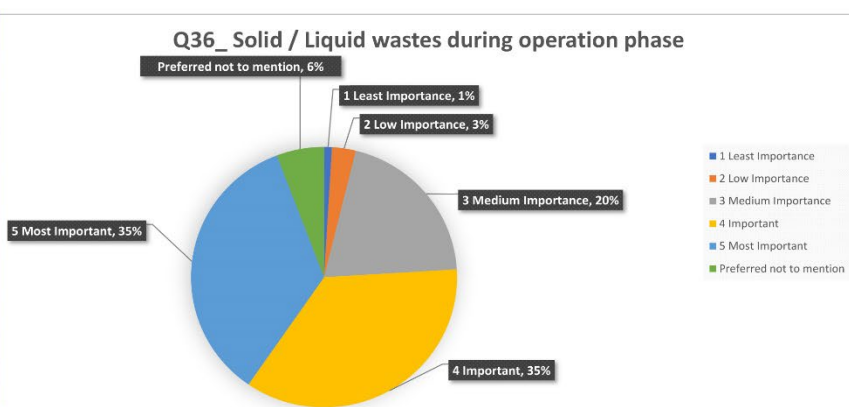
| Q34_ Material use during operation phase | Respondents | Percent | Score |
|--|-------------|---------|-------|
| 1 Least Importance | 2 | 1.92% | 0.2 |
| 2 Low Importance | 7 | 6.73% | 0.4 |
| 3 Medium Importance | 16 | 15.38% | 0.6 |
| 4 Important | 33 | 31.73% | 0.8 |
| 5 Most Important | 41 | 39.42% | 1 |
| Preferred not to mention | 5 | 4.81% | |
| Total | 104 | 100% | 80.2 |
| | 80.2 | 81.01% | 99 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 99 | 0.81 | 0.8 |



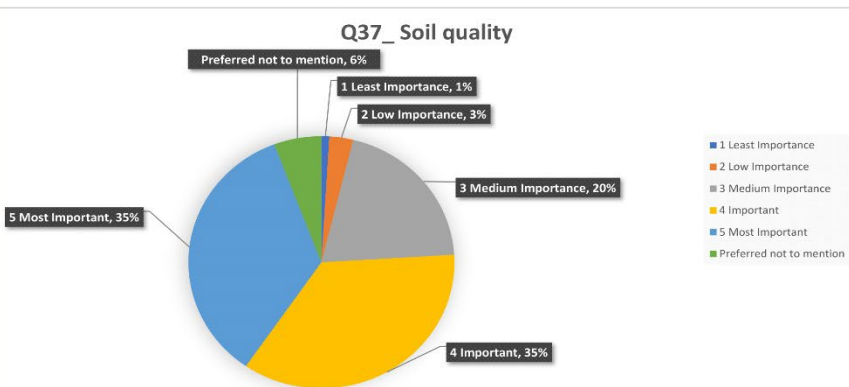
| Q35_ Solid / Liquid wastes during construction phase | Respondents | Percent | Score |
|--|-------------|---------|-------|
| 1 Least Importance | 0 | 0.00% | 0.2 |
| 2 Low Importance | 8 | 7.69% | 0.4 |
| 3 Medium Importance | 23 | 22.12% | 0.6 |
| 4 Important | 34 | 32.69% | 0.8 |
| 5 Most Important | 33 | 31.73% | 1 |
| Preferred not to mention | 6 | 5.77% | |
| Total | 104 | 100% | 77.2 |
| | 77.2 | 78.78% | 98 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 98 | 0.79 | 0.8 |



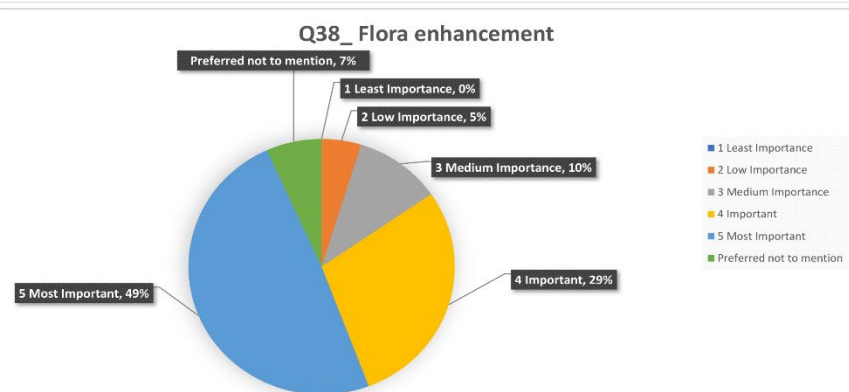
| Q36_ Solid / Liquid wastes during operation phase | Respondents | Percent | Score |
|---|-------------|---------|-------|
| 1 Least Importance | 1 | 0.96% | 0.2 |
| 2 Low Importance | 3 | 2.88% | 0.4 |
| 3 Medium Importance | 21 | 20.19% | 0.6 |
| 4 Important | 37 | 35.58% | 0.8 |
| 5 Most Important | 36 | 34.62% | 1 |
| Preferred not to mention | 6 | 5.77% | |
| Total | 104 | 100% | 79.6 |
| | 79.6 | 81.22% | 98 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 98 | 0.81 | 0.8 |



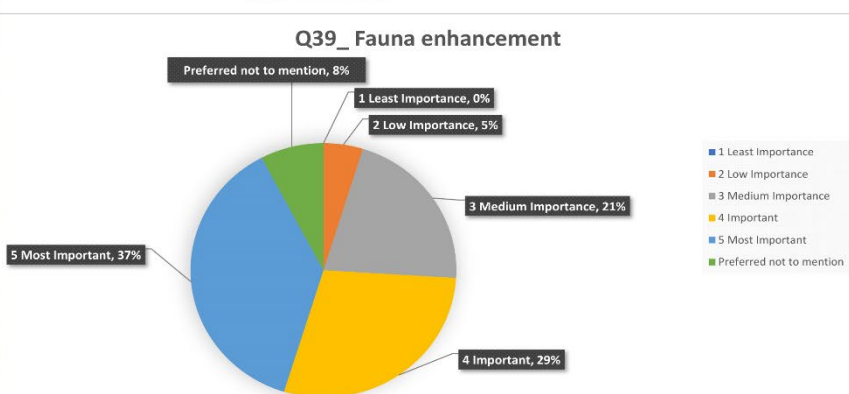
| Q37_ Soil quality | Respondents | Percent | Score |
|---------------------------------------|-------------|---------|-------|
| 1 Least Importance | 1 | 0.96% | 0.2 |
| 2 Low Importance | 3 | 2.88% | 0.4 |
| 3 Medium Importance | 21 | 20.19% | 0.6 |
| 4 Important | 37 | 35.58% | 0.8 |
| 5 Most Important | 36 | 34.62% | 1 |
| Preferred not to mention | 6 | 5.77% | |
| Total | 104 | 100% | 79.6 |
| | 79.6 | 81.22% | 98 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 98 | 0.81 | 0.8 |



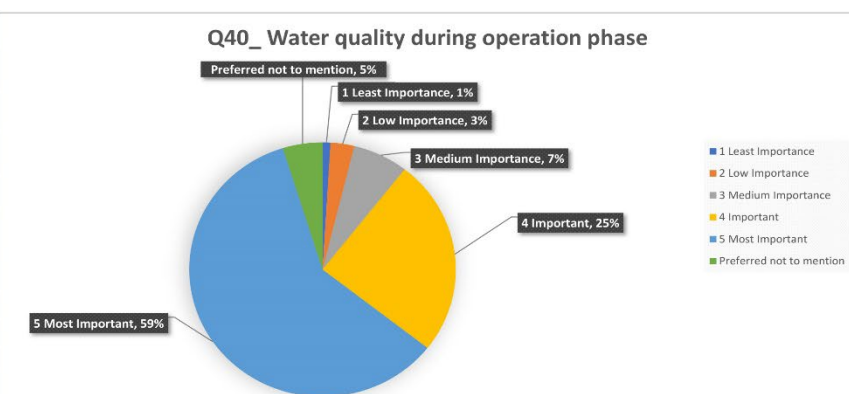
| Q38_ Flora enhancement | Respondents | Percent | Score |
|---------------------------------------|-------------|---------|-------|
| 1 Least Importance | 0 | 0.00% | 0.2 |
| 2 Low Importance | 5 | 4.81% | 0.4 |
| 3 Medium Importance | 11 | 10.58% | 0.6 |
| 4 Important | 30 | 28.85% | 0.8 |
| 5 Most Important | 51 | 49.04% | 1 |
| Preferred not to mention | 7 | 6.73% | |
| Total | 104 | 100% | 83.6 |
| | 83.6 | 86.19% | 97 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 97 | 0.86 | 0.9 |



| Q39_ Fauna enhancement | Respondents | Percent | Score |
|---------------------------------------|-------------|---------|-------|
| 1 Least Importance | 0 | 0.00% | 0.2 |
| 2 Low Importance | 5 | 4.81% | 0.4 |
| 3 Medium Importance | 22 | 21.15% | 0.6 |
| 4 Important | 30 | 28.85% | 0.8 |
| 5 Most Important | 39 | 37.50% | 1 |
| Preferred not to mention | 8 | 7.69% | |
| Total | 104 | 100% | 78.2 |
| | 78.2 | 81.46% | 96 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 96 | 0.81 | 0.8 |



| Q40_ Water quality during operation phase | Respondents | Percent | Score |
|---|-------------|---------|-------|
| 1 Least Importance | 1 | 0.96% | 0.2 |
| 2 Low Importance | 3 | 2.88% | 0.4 |
| 3 Medium Importance | 7 | 6.73% | 0.6 |
| 4 Important | 26 | 25.00% | 0.8 |
| 5 Most Important | 62 | 59.62% | 1 |
| Preferred not to mention | 5 | 4.81% | |
| Total | 104 | 100% | 88.4 |
| | 88.4 | 89.29% | 99 |
| $WAI = \frac{\sum f_i w_i}{\sum f_i}$ | 99 | 0.89 | 0.9 |



Appendix (3) Native Species in Egypt

The tables below show the Native species in Egypt according to the Royal Botanic Gardens, Plants of the World Online

Table A: Native Species in Egypt: Genus

Table (A) Native Genus in Egypt according to Royal Botanic Gardens, Kew, Online, Source: RBG Kew, 2021

| Nu | Name | Nu | Name | Nu | Name | Nu | Name | Nu | Name | Nu | Name | Nu | Name |
|----|-----------------------------------|-----|--------------------------------------|-----|---|-----|-------------------------------------|-----|---------------------------------------|-----|------------------------------------|-----|-------------------------------|
| 1 | Avicennia L. | 101 | Leopoldia Parl. | 201 | Alkanna Tausch | 301 | Telephium L. | 401 | Tripodion Medik. | 501 | Kickxia Dumort. | 601 | Tragus Haller |
| 2 | Barleria L. | 102 | Muscari Mill. | 202 | Anchusa L. | 302 | Ceratophyllum L. | 402 | Vachella Wight & Arn. | 502 | Limosella L. | 602 | Tricholaena Schrad. |
| 3 | Blepharis Juss. | 103 | Ornithogalum L. | 203 | Arnebia Forssk. | 303 | Fumana (Dunal) Spach | 403 | Vicia L. | 503 | Linaria Mill. | 603 | Trichoneura Andersson |
| 4 | Dicliptera Juss. | 104 | Scilla L. | 204 | Buglossoides Moench | 304 | Helianthemum Mill. | 404 | Vigna Savi | 504 | Misopates Raf. | 604 | Triplachne Link |
| 5 | Aizoon L. | 105 | Asphodelus L. | 205 | Coldenia L. | 305 | Cleome L. | 405 | Frankenia L. | 505 | Nanorrhinum Betsche | 605 | Triraphis R.Br. |
| 6 | Mesembryanthemum L. | 106 | Achillea L. | 206 | Cordia L. | 306 | Colchicum L. | 406 | Centaurium Hill | 506 | Plantago L. | 606 | Trisetaria Forssk. |
| 7 | Trianthema L. | 107 | Aetheorhiza Cass. | 207 | Echiochilon Desf. | 307 | Commelina Plum. ex L. | 407 | Schenkia Griseb. | 507 | Veronica L. | 607 | Triticum L. |
| 8 | Zaleya Burm.f. | 108 | Ageratum L. | 208 | Echium Tourn. ex L. | 308 | Calyptegia R.Br. | 408 | Erodium L'Hér. ex Aiton | 508 | Limoniastrum Heist. ex Fabr. | 608 | Urochloa P.Beauv. |
| 9 | Alisma L. | 109 | Amorpha L. | 209 | Euploca Nutt. | 309 | Convolvulus L. | 409 | Geranium Tourn. ex L. | 509 | Limonium Mill. | 609 | Vossia Wall. & Griff. |
| 10 | Caldesia Parl. | 110 | Anacyclus L. | 210 | Gastrocotyle Bunge | 310 | Cressa L. | 410 | Monsonia L. | 510 | Achnatherum P.Beauv. | 610 | Zea L. |
| 11 | Damasonium Mill. | 111 | Anthemis L. | 211 | Heliotropium Tourn. ex L. | 311 | Cuscuta L. | 411 | Gisekia L. | 511 | Acrachne Wight & Arn. ex Chiov. | 611 | Tristicha Thouars |
| 12 | Achyranthes L. | 112 | Artemisia L. | 212 | Lappula Moench | 312 | Dichondra J.R.Forst. & G.Forst. | 412 | Myriophyllum Ponted. ex L. | 512 | Aegilops L. | 612 | Polygala Tourn. ex L. |
| 13 | Aerva Forssk. | 113 | Asteriscus Moench | 213 | Microparacaryum (Pegoe ex Riedl) | 313 | Ipomoea L. | 413 | Elodea Michx. | 513 | Aeluropus Trin. | 613 | Atraphaxis L. |
| 14 | Agathophora (Fenzl) Bunge | 114 | Attractylis L. | 214 | Moltkiopsis I.M.Johnst. | 314 | Seddera Hochst. | 414 | Halophila Thouars | 514 | Agropyron Gaertn. | 614 | Calligonum L. |
| 15 | Alternanthera Forssk. | 115 | Baccharoides Moench | 215 | Nonea Medik. | 315 | Crassula L. | 415 | Najas L. | 515 | Alopecurus L. | 615 | Fallugia Adans. |
| 16 | Amaranthus L. | 116 | Bidens L. | 216 | Ogastemma Brummitt | 316 | Umbilicus DC. | 416 | Ottelia Pers. | 516 | Ammodhloa Boiss. | 616 | Persicaria Mill. |
| 17 | Anabasis L. | 117 | Blainvillea Cass. | 217 | Podonosma Boiss. | 317 | Bryonia L. | 417 | Thalassia Barles & Sol. ex K.D.Koenig | 517 | Apera Adans. | 617 | Polygonum L. |
| 18 | Arthrocaulon Pirainen & G. Lohman | 118 | Blumea DC. | 218 | Trichodesma R.Br. | 318 | Citrullus Schrad. ex Eckl. & Zeyh | 418 | Vallisneria P. Micheli ex L. | 518 | Aristida L. | 618 | Rumex L. |
| 19 | Arthrocaulon Pirainen & G. Lohman | 119 | Brocchia Vis. | 219 | Alyssum L. | 319 | Coccinia Wight & Arn. | 419 | Adiantum L. | 519 | Arundo L. | 619 | Pontederia L. |
| 20 | Atriplex L. | 120 | Calendula L. | 220 | Arabis L. | 320 | Cucumis L. | 420 | Moraea Mill. | 520 | Avena L. | 620 | Portulaca L. |
| 21 | Bassia All. | 121 | Carduus L. | 221 | Biscutella L. | 321 | Cymodactyle K.D. Koenig | 421 | Juncus L. | 521 | Brachypodium P.Beauv. | 621 | Posidonia K.D. Koenig |
| 22 | Beta L. | 122 | Carlinia L. | 222 | Brassica L. | 322 | Halodule Endl. | 422 | Aluja L. | 522 | Brius L. | 622 | Potamogeton L. |
| 23 | Caroxylon Thunb. | 123 | Carthamus L. | 223 | Cakile Mill. | 323 | Oceana Byng & Christenh. | 423 | Ballota L. | 523 | Bromus L. | 623 | Stuckenia Börner |
| 24 | Chenopodiastrium S.Fuentes | 124 | Centaurea L. | 224 | Camelina Crantz | 324 | Syringodium Kütz. | 424 | Clerodendrum L. | 524 | Calamagrostis Adans. | 624 | Zannichellia P. Micheli ex L. |
| 25 | Chenopodium L. | 125 | Ceranea Forssk. | 225 | Capella Medik. | 325 | Thalassodendron Hartog | 425 | Coleus Lour. | 525 | Catapodium Link | 625 | Coris L. |
| 26 | Comulaca Delle | 126 | Chiladendron Cass. | 226 | Carrichtera DC. | 326 | Cynomolium L. | 426 | Lamium L. | 526 | Cenchrus L. | 626 | Lysimachia Tourn. ex L. |
| 27 | Digera Forssk. | 127 | Chlamydomorpha Ehrenb. ex Less. | 227 | Coincya Rouy | 327 | Bolboschoenus (Asch.) Palla | 427 | Lavandula L. | 527 | Centropodia Rchb. | 627 | Samolus L. |
| 28 | Dysphania R.Br. | 128 | Chrysanthellum Rich. | 228 | Conringia Heist. ex Fabr. | 328 | Carex L. | 428 | Leucas R.Br. | 528 | Chloris Sw. | 628 | Actinopteryx Link |
| 29 | Halocnemum M.Bieb. | 129 | Cichorium L. | 229 | Cuprella Salmerón-Sánchez, Moya & Rueda | 329 | Cladium P.Browne | 429 | Marrubium L. | 529 | Calochrysum Hochst. & Nees | 629 | Salicornia L. |
| 30 | Halopogon Bunge ex Ung.-Ster | 130 | Cladanthus Cass. | 230 | Descurainia Webb & Berthel. | 330 | Cyperus L. | 430 | Mentha L. | 530 | Coix L. | 630 | Anogramma Link |
| 31 | Haloxylon Bunge ex Fenzl | 131 | Cotula L. | 231 | Dichasanthus Ovcz. & Yunusov | 331 | Eleocharis R.Br. | 431 | Micromeria Benth. | 531 | Cortaderia Stapf | 631 | Cosentinia Tod. |
| 32 | Krascheninnikovia Gueldenst. | 132 | Crepis L. | 232 | Didesmus Desv. | 332 | Fimbristylis Vahl | 432 | Cocum L. | 532 | Corynephorus P.Beauv. | 632 | Adonis L. |
| 33 | Noaea Moq. | 133 | Crocodilium Hill | 233 | Diplotaxis DC. | 333 | Fuirena Rotb. | 433 | Orthosiphon Benth. | 533 | Crithopsis Jaub. & Spach | 633 | Anemone L. |
| 34 | Ouret Adans. | 134 | Crupina (Pers.) DC. | 234 | Enarthrocarpus Labill. | 334 | Isoplepis R.Br. | 434 | Otostegia Benth. | 534 | Cutandia Willk. | 634 | Delphinium Tourn. ex L. |
| 35 | Oxybasis Kar. & Kir. | 135 | Cynara L. | 235 | Eremobium Boiss. | 335 | Schoenoplectiella Lye | 435 | Phlomis L. | 535 | Cymbopogon Spreng. | 635 | Nigella L. |
| 36 | Salicornia L. | 136 | Daveaua Willk. ex Mariz | 236 | Eruca Mill. | 336 | Schoenoplectus (Rchb.) Palla | 436 | Prasium L. | 536 | Cynodon Rich. | 636 | Ranunculus L. |
| 37 | Salsola L. | 137 | Dittichia Greuter | 237 | Eruca Gaertn. | 337 | Scirpoides Scd. | 437 | Pseudodictamnus Fabr. | 537 | Cynosurus L. | 637 | Cayusea A.St.-Hil. |
| 38 | Seidlitzia Bunge ex Boiss. | 138 | Echinops L. | 238 | Eucastrum (DC.) C.Presl | 338 | Pteridium Gleditsch | 438 | Salvia L. | 538 | Dactylis L. | 638 | Ochradenus Delle |
| 39 | Sevada Moq. | 139 | Eclipta L. | 239 | Erysimum Tourn. ex L. | 339 | Euclea L. | 439 | Stachys L. | 539 | Dactyloctenium Willd. | 639 | Oligomeris Cambess. |
| 40 | Suaeda Forssk. ex J.F. Gmel. | 140 | Erigeron L. | 240 | Farsetia Turra | 340 | Bergia L. | 440 | Tetrum L. | 540 | Dianthus P.Beauv. | 640 | Randonia Coss. |
| 41 | Traganum Delile | 141 | Ethulia L.f. | 241 | Fibigia Medik. | 341 | Elatine L. | 441 | Thymra L. | 541 | Desmazeria Dumort. | 641 | Reseda Tourn. ex L. |
| 42 | Allium L. | 142 | Filago Loeffl. | 242 | Hormungia Rchb. | 342 | Ephedra Tourn. ex L. | 442 | Thymus L. | 542 | Desmodium (Stapf) Stapf | 642 | Rhamnus L. |
| 43 | Narcissus L. | 143 | Flaveria Juss. | 243 | Isatis Tourn. ex L. | 343 | Chrozophora Neck. ex A.Juss. | 443 | Vitea L. | 543 | Dichanthium Willmet | 643 | Ziziphium Mill. |
| 44 | Nothoscordium Kunth | 144 | Garhadiolus Jaub. & Spach | 244 | Lepidium L. | 344 | Euphorbia L. | 444 | Volkameria L. | 544 | Volkameria L. | 644 | Rhizophora L. |
| 45 | Pancratium Dill. ex L. | 145 | Gelasia Cass. | 245 | Leptaleum DC. | 345 | Mercurialis L. | 445 | Utricularia L. | 545 | Dinebra Jacq. | 645 | Cataegus L. |
| 46 | Pistacia L. | 146 | Geropogon L. | 246 | Lobularia Desv. | 346 | Ricinus L. | 446 | Gagea Salisb. | 546 | Dicladia P.Beauv. | 646 | Potentilla L. |
| 47 | Searsia F.A.Barkley | 147 | Glebionis Cass. | 247 | Malcolmia W.T.Aiton | 347 | Aeschynomene L. | 447 | Tulipa L. | 547 | Echinochloa P.Beauv. | 647 | Rubus L. |
| 48 | Ammi L. | 148 | Gnaphalium L. | 248 | Maresia Pomet | 348 | Albizia Durazz. | 448 | Limeum L. | 548 | Eharta Thunb. | 648 | Sanguisorba L. |
| 49 | Ammodaucus Coss. | 149 | Gnomophallium Greuter | 249 | Matthiola W.T.Aiton | 349 | Alhai Tourn. ex Gagnebin | 449 | Linum L. | 549 | Eleusine Gaertn. | 649 | Callipetris Steven |
| 50 | Ammodaucus Coss. | 150 | Gnaphalium Greuter | 250 | Moretia DC. | 350 | Anagyris L. | 450 | Lindernia All. | 550 | Eleonorus Humb. & Bonpl. ex Willd. | 650 | Cucurbitaria L. |
| 51 | Anthriscus Pers. | 151 | Gymnarrhena Desf. | 251 | Moricandia DC. | 351 | Anthyllus L. | 451 | Plicosepalus Tiegh. | 551 | Enneapogon Desv. ex P.Beauv. | 651 | Cruciata Mill. |
| 52 | Apium L. | 152 | Hedynopsis Mill. | 252 | Nasturtium Boiss. | 352 | Argyrobolus Eckl. & Zeyh. | 452 | Ammannia L. | 552 | Enteropogon Nees | 652 | Galium L. |
| 53 | Berula W.D.J.Koch | 153 | Helichrysum Mill. | 253 | Nasturtium W.T.Aiton | 353 | Astragalus L. | 453 | Lythrum L. | 553 | Eragrostis Wolf | 653 | Kohautia Cham. & Schtdt. |
| 54 | Bupleurum L. | 154 | Helminthotheca Zinn | 254 | Neotolaria Hedge & J.Léonard | 354 | Biserrula L. | 454 | Abutilon Mill. | 554 | Festuca Tourn. ex L. | 654 | Oldenlandia L. |
| 55 | Coriandrum L. | 155 | Heteroderis Boiss. | 255 | Neslia Desv. | 355 | Caesalpinia Plum. ex L. | 455 | Alcea L. | 555 | Gastridium P.Beauv. | 655 | Plocama Aiton |
| 56 | Crithmum L. | 156 | Hyoseris L. | 256 | Notoceras W.T.Aiton | 356 | Cajanus Adans. | 456 | Corchorus L. | 556 | Halopyrum Stapf | 656 | Thelliptegium L. |
| 57 | Cyclospermum Lag. | 157 | Ifigia Cass. | 257 | Ochthodium DC. | 357 | Cassia L. | 457 | Gossypium L. | 557 | Hemarthria R.Br. | 657 | Valantia L. |
| 58 | Daucus L. | 158 | Iphione Cass. | 258 | Pseudoceraia O.E. Schulz | 358 | Cicer L. | 458 | Grewia L. | 558 | Holcus L. | 658 | Ruppia L. |
| 59 | Deverra DC. | 159 | Koelipia Pall. | 259 | Raphanus L. | 359 | Citronia L. | 459 | Hermannia L. | 559 | Hordeum L. | 659 | Citrus L. |
| 60 | Ducrocia Boiss. | 160 | Lactuca L. | 260 | Rapistrum Crantz | 360 | Coronilla L. | 460 | Hibiscus L. | 560 | Hyperthia Andersson ex E.Fou | 660 | Haplophyllum A.Juss. |
| 61 | Eryngium Tourn. ex L. | 161 | Lasiopogon Cass. | 261 | Rorippa Scop. | 361 | Corallaria L. | 461 | Malva Tourn. ex L. | 561 | Imperata Cirillo | 661 | Populus L. |
| 62 | Ferula Tourn. ex L. | 162 | Launaea Cass. | 262 | Savignya DC. | 362 | Cullen Medik. | 462 | Malvastrum A.Gray | 562 | Lagurus L. | 662 | Salix L. |
| 63 | Foeniculum Mill. | 163 | Leontodon L. | 263 | Schimperia Steud. & Hochst. ex Endl. | 363 | Delonix Raf. | 463 | Pavonia Cav. | 563 | Lamarckia Moench | 663 | Salvadora Garcin ex L. |
| 64 | Helosciadium W.D.J.Koch | 164 | Leysera L. | 264 | Schouwia DC. | 364 | Dichrostachys (A.D.C.) Wight & Arn. | 464 | Sida L. | 564 | Lasiurus Boiss. | 664 | Thesium L. |
| 65 | Leiotulus Ehrenb. | 165 | Limbaria Adans. | 265 | Sinapis L. | 365 | Ebenus L. | 465 | Marsilea L. | 565 | Leersia Sw. | 665 | Cardiospermum L. |
| 66 | Petroselinum Hill | 166 | Mantisca Cass. | 266 | Sisymbrium L. | 366 | Erythrina L. | 466 | Cocculus DC. | 566 | Leptochloa P.Beauv. | 666 | Anticharis Endl. |
| 67 | Pimpinella L. | 167 | Martica L. | 267 | Zilla Forssk. | 367 | Falderia A.Chev. | 467 | Glinus L. | 567 | Leptochloa P.Beauv. | 667 | Brauneria Kunth |
| 68 | Scandix L. | 168 | Microrhiza DC. | 268 | Commiphora Jacq. | 368 | Glycyrrhiza Tourn. ex L. | 468 | Ficus Tourn. ex L. | 568 | Lolium L. | 668 | Scrophularia Tourn. ex L. |
| 69 | Stolbrax Raf. | 169 | Campanula L. | 269 | Campylura L. | 369 | Gullandina L. | 469 | Moringa Adans. | 569 | Lygeum Loeffl. ex L. | 669 | Verbascum L. |
| 70 | Tordylium Tourn. ex L. | 170 | Notobasis Cass. | 270 | Legosia Durande | 370 | Haematoxylum L. | 470 | Neurada B.Juss. | 570 | Megathyrus (Peg.) B.S. & Lohman | 670 | Datura L. |
| 71 | Tonlis Adans. | 171 | Onopordum L. | 271 | Wahlenbergia Schrad. ex Roth | 371 | Hippocrepis L. | 471 | Nitraria L. | 571 | Melanocentris Nees | 671 | Hyoscyamus Tourn. ex L. |
| 72 | Vinsaga Mill. | 172 | Osteospermum L. | 272 | Cadaba Forssk. | 372 | Indigofera L. | 472 | Peganum L. | 572 | Melinis P.Beauv. | 672 | Lycium L. |
| 73 | Zosima Hoffm. | 173 | Pallenis (Cass.) Cass. | 273 | Capparis Tourn. ex L. | 373 | Lathyrus L. | 473 | Tetradiclis Steven ex M.Bieb. | 573 | Miscanthus Andersson | 673 | Nicandra Adans. |
| 74 | Alafia Thouars | 174 | Phagnalon Cass. | 274 | Maena Forssk. | 374 | Leobordea Delile | 474 | Boerhavia Vaill. ex L. | 574 | Moorochloa Veldkamp | 674 | Nicotiana L. |
| 75 | Apteranthes J.C.Mikan | 175 | Picris L. | 275 | Cephalaria Schrad. | 375 | Leucaena Benth. | 475 | Commicarpus Standl. | 575 | Oloptum Röser & Hamasha | 675 | Physalis L. |
| 76 | Calotropis R.Br. | 176 | Pluchea Cass. | 276 | Lomelosia Raf. | 376 | Lotus L. | 476 | Nymphaea L. | 576 | Oryza L. | 676 | Solanum L. |
| 77 | Carissa L. | 177 | Pseudoconyza Cuatrec. | 277 | Pterocarpus Vaill. ex Adans. | 377 | Lupinus L. | 477 | Olea L. | 577 | Panicum L. | 677 | Withania Pauguy |
| 78 | Cynanchum L. | 178 | Pseudopodopernum (Egmont & Weylandt) | 278 | Scabiosa L. | 378 | Medicago L. | 478 | Epilobium Dill. ex L. | 578 | Parapholis C.E. Hubb. | 678 | Sphenoclea Gaertn. |
| 79 | Gomphocarpus R.Br. | 179 | Pulicaria Gaertn. | 279 | Valeriana L. | 379 | Mellilotus Mill. | 479 | Ludwigia L. | 579 | Parapholis C.E. Hubb. | 679 | Reaumuria L. |
| 80 | Leptadenia R.Br. | 180 | Reichardia Roth | 280 | Valerianella Mill. | 380 | Mimosa L. | 480 | Oenothera L. | 580 | Phalaris L. | 680 | Tamarix L. |
| 81 | Oxytelma R.Br. | 181 | Rhagadiolus Juss. | 281 | Arenaria Ruppius ex L. | 381 | Onobrychis Mill. | 481 | Ophiochloa L. | 581 | Phleum L. | 681 | Thymelaea Mill. |
| 82 | Pentstemon R.Br. ex Wight & Arn. | 182 | Scolymus Tourn. ex L. | 282 | Atocion Adans. | 382 | Ononis L. | 482 | Bellardia All. | 582 | Phragmites Adans. | 682 | Typha L. |
| 83 | Pergularia L. | 183 | Scorzonera L. | 283 | Cometes L. | 383 | Pithecellobium Mart. | 483 | Cistanche Hoffmanns. & Link | 583 | Posa L. | 683 | Forsskaolea L. |
| 84 | Periploca Tourn. ex L. | 184 | Scorzonoides Moench | 284 | Dianthus L. | 384 | Pongamia Adans. | 484 | Lindenbergia Lehm. | 584 | Polypogon Desf. | 684 | Parietaria L. |
| 85 | Rhazya Decne. | 185 | Senecio L. | 285 | Eremogone Fenzl | 385 | Prosopis L. | 485 | Orobancha L. | 585 | Roritaria Trin. | 685 | Urtica L. |
| 86 | Solenostemma Hayne | 186 | Silybum Adans. | 286 | Gymnocarpus Forssk. | 386 | Spodopocarpus Neck. ex DC. | 486 | Parentucella Viv. | 586 | Sacharum L. | 686 | Vahlia Thunb. |
| 87 | Arisarum Mill. | 187 | Sonchus L. | 287 | Gypsophila L. | 387 | Retama Raf. | 487 | Striga Lour. | 587 | Sorghum P.Beauv. | 687 | Lantana L. |
| 88 | Biarum Schott | 188 | Sphaeranthus L. | 288 | Herniaria Tourn. ex L. | 388 | Rhynchosia Lour. | 488 | Oxalis L. | 588 | Schmidtia Steud. ex J.A. Schmidt | 688 | Phyla Lour. |
| 89 | Eriminum Schott | 189 | Loeflingia L. | 289 | Loeflingia L. | 389 | Saraca L. | 489 | Argemone L. | 589 | Schnefeldia Kunth | 689 | Priva Adans. |
| 90 | Lemna L. | 190 | Symphyotrichum Nees | 290 | Paronychia Mill. | 390 | Scorpiurus L. | 490 | Fumaria Tourn. ex L. | 590 | Serapia P.Beauv. | 690 | Verbena L. |
| 91 | Pistia L. | 191 | Tagetes L. | 291 | Petrarchia (Ser. ex DC.) Link | 391 | Senegalia Raf. | 491 | Glaucium Mill. | 591 | Sorghum Moench | 691 | Viola L. |
| 92 | Spirodela Schleid. | 192 | Taraxacum F.H.Wigg. | 292 | Polycarpea Lam. | 392 | Senna Mill. | 492 | Hypocoum Tourn. ex L. | 592 | Sphenopus | | |

Table B: Native Species in Egypt: Species

Table (B) Native Species in Egypt according to Royal Botanic Gardens, Kew, Online, Source: RBG Kew, 2021

| Nu | Name | Nu | Name | Nu | Name | Nu | Name | Nu | Name |
|----|---|-----|---|-----|--|-----|--|-----|--|
| 1 | Avicennia marina (Forssk.) Vierh. | 101 | Psilotrichum gnaphalobryum (Hochst.) Schinz | 201 | Torilis leptophylla (L.) Rchb.f. | 301 | Bidens bipinnata L. | 401 | Lasiopogon muscoides (Desf.) DC. |
| 2 | Barleria acanthoides Vahl | 102 | Pupalia figareli Tod. | 202 | Torilis nodosa (L.) Gaertn. | 302 | Bidens biternata (Lour.) Merr. & Sherff | 402 | Launaea angustifolia (Desf.) Kuntze |
| 3 | Blepharis attenuata Napper | 103 | Pupalia lappacea (L.) Juss. | 203 | Torilis tenella (Delile) Rchb.f. | 303 | Bidens pilosa L. | 403 | Launaea capitata (Spreng.) Dandy |
| 4 | Blepharis edulis (Forssk.) Pers. | 104 | Salicornia fruticosa (L.) L. | 204 | Trachyspermum ammi (L.) Sprague | 304 | Bidens schimperii Sch.Bip. ex Walp. | 404 | Launaea fragilis (Asso) Pau |
| 5 | Dicliptera paniculata (Forssk.) I.Darbysh. | 105 | Salicornia perennans Willd. | 205 | Vinsaga daucoides Gaertn. | 305 | Blainvillaea acmella (L.) Philipson | 405 | Launaea intybacea (Jacq.) Beauverd |
| 6 | Justicia heterocarpa T.Anderson | 106 | Salicornia perennis Mill. | 206 | Zosima absinthifolia (Vent.) Link | 306 | Blumea bovei (DC.) Vatke | 406 | Launaea massauensis (Fresen.) Sch.Bip. ex Kuntze |
| 7 | Justicia odora (Forssk.) Lam. | 107 | Salsola kali L. | 207 | Alafia multiflora (Stapf) Stapf | 307 | Brochia cinerea (Delile) Vis. | 407 | Launaea mucronata (Forssk.) Muschl. |
| 8 | Ruellia patula Jacq. | 108 | Salsola longifolia Forssk. | 208 | Apteranthes europaea (Guss.) Murb. | 308 | Calendula arvensis L. | 408 | Launaea nudicaulis (L.) Hook.f. |
| 9 | Alzanthemopsis hispanica (L.) Klak | 109 | Salsola nitida E.D.Clarke | 209 | Calotropis procera (Aiton) W.T.Aiton | 309 | Calendula tripterocarpa Rupr. | 409 | Launaea procumbens (Roxb.) Ramayya & Rajagopal |
| 10 | Alzoon canariense L. | 110 | Salsola oppositifolia Desf. | 210 | Carissa spinarum L. | 310 | Carduus acicularis Bertol. | 410 | Launaea spinosa (Forsk.) Sch.Bip. ex Kuntze |
| 11 | Mesembryanthemum cryptanthum Hook.f. | 111 | Salsola pontica (Pall.) Ilin | 211 | Cynanchum acutum L. | 311 | Carduus arabicus Jacq. ex Murray | 411 | Leontodon tuberosus L. |
| 12 | Mesembryanthemum crystallinum L. | 112 | Salsola schweinfurthii Solms | 212 | Cynanchum boveanum Decne. | 312 | Carduus argentatus L. | 412 | Leysera leyseroides (Desf.) Maire |
| 13 | Mesembryanthemum nodiflorum L. | 113 | Seidlitzia rosmarinus Bunge ex Boiss. | 213 | Gomphocarpus sinaius Boiss. | 313 | Carduus getulus Pomel | 413 | Umbarda crithmoides (L.) Dumort. |
| 14 | Trianthema triquetrum Willd. ex Spreng. | 114 | Sevada schimperii Moq. | 214 | Leptadenia arborea (Forssk.) Schweinf. | 314 | Carduus pycnocephalus L. | 414 | Mantisia salmantica (L.) Brig. & Cavill. |
| 15 | Zaleya pentandra (L.) C.Jeffrey | 115 | Suaeda aegyptiaca (Hasselq.) Zohary | 215 | Leptadenia pyrotechnica (Forssk.) Decne. | 315 | Carlina curetum Heldr. | 415 | Matricaria aurea (Loefl.) Sch.Bip. |
| 16 | Alisma gramineum L. | 116 | Suaeda altissima (L.) Pall. | 216 | Oxytelus esculentum (L.) Sm. | 316 | Carlina sicula Ten. | 416 | Matricaria chamomilla L. |
| 17 | Alisma plantago-aquatica L. | 117 | Suaeda fruticosa Forssk. ex J.F.Gmel. | 217 | Pentstemon nivalis (J.F.Gmel.) D.V.Field & J.R.J.Wood | 317 | Carthamus eriocephalus (Boiss.) Greuter | 417 | Microglossa pyrrhopappa (A.Rich.) Agnew |
| 18 | Caldesia parnassifolia (Bassil) Parl. | 118 | Suaeda maritima (L.) Dumort. | 218 | Pergularia tomentosa L. | 318 | Carthamus glaucus M.Bieb. | 418 | Nidorella aegyptiaca (L.) J.C.Manning & Goldblatt |
| 19 | Damasionium bourgaei Coss. | 119 | Suaeda monica Forssk. ex J.F.Gmel. | 219 | Periploca angustifolia Labill. | 319 | Carthamus lanatus L. | 419 | Notobasis syriaca (L.) Cass. |
| 20 | Achyranthes aspera L. | 120 | Suaeda palaestina Eig & Zohary | 220 | Rhazya greisii Täckh. & Boulos | 320 | Carthamus mareoticus Delile | 420 | Onopordum alexandrinum Boiss. |
| 21 | Aerva javanica (Burm.f.) Juss. ex Schult. | 121 | Suaeda pinnatifida Delile | 221 | Solenostemma oleifolium (Nectoux) Bullock & E.A.Bruce ex Maire | 321 | Carthamus tenuis (Boiss. & C.I.Blanche) Bornm. | 421 | Onopordum ambiguum Fresen. |
| 22 | Agathophora alopecuroides (Delile) Fenzl ex Bunge | 122 | Suaeda pruinosa Lange | 222 | Arisarum vulgare O.Targ.Tozz. | 322 | Carthamus tincturius L. | 422 | Onopordum cardifolium Boiss. |
| 23 | Alternanthera pungens Kunth | 123 | Suaeda splendens (Pourr.) Gren. & Godr. | 223 | Biarum olivieri Blume | 323 | Centauria aegyptiaca L. | 423 | Onopordum caulescens d'Urv. |
| 24 | Alternanthera sessilis (L.) R.Br. ex DC. | 124 | Suaeda vera Forssk. ex J.F.Gmel. | 224 | Eminium spiculatum (Blume) Schott | 324 | Centauria angustifolia Delile | 424 | Osteospermum vaillantii (Decne.) Norl. |
| 25 | Amaranthus albus L. | 125 | Suaeda vermiculata Forssk. ex J.F.Gmel. | 225 | Lemna aquinoctialis Welw. | 325 | Centauria bimorpha Viv. | 425 | Pallenis hierochuntica (Michon) Greuter |
| 26 | Amaranthus bioides S.Watson | 126 | Tragacanthum nudatum Delile | 226 | Lemna gibba L. | 326 | Centauria calcitrapa L. | 426 | Pallenis spinosa (L.) Cass. |
| 27 | Amaranthus bitum L. | 127 | Allium ampeloprasum L. | 227 | Lemna minor L. | 327 | Centauria eryngioides Lam. | 427 | Phagnalon barbeyanum Asch. & Schweinf. |
| 28 | Amaranthus caudatus L. | 128 | Allium aristatum L. | 228 | Pistia stratiotes L. | 328 | Centauria furfuracea Coss. & Durieu | 428 | Phagnalon rupestre (L.) DC. |
| 29 | Amaranthus cruentus L. | 129 | Allium ascalonicum L. | 229 | Spirodelia oligorhiza (Kurz) Hegelm. | 329 | Centauria glomerata Vahl | 429 | Phagnalon schweinfurthii Sch.Bip. ex Schweinf. |
| 30 | Amaranthus graecians L. | 130 | Allium barthianum Asch. & Schweinf. | 230 | Spirodelia polyrhiza (L.) Schleid. | 330 | Centauria melitensis L. | 430 | Picris amalecitana (Boiss.) Eig |
| 31 | Amaranthus hybridus L. | 131 | Allium bifloridum Asch. & Schweinf. | 231 | Wolffia hyalina (Delile) Monod | 331 | Centauria pallescens Delile | 431 | Picris asplenoides L. |
| 32 | Amaranthus palmeri S.Watson | 132 | Allium cepa L. | 232 | Borassus aethiops Mart. | 332 | Centauria postii Boiss. | 432 | Picris cyanocarpa Boiss. |
| 33 | Amaranthus retrofractus L. | 133 | Allium coppersleyi Tineo | 233 | Hyphaene thebaica (L.) Mart. | 333 | Centauria pullata L. | 433 | Picris kotschy Boiss. |
| 34 | Amaranthus spinosus L. | 134 | Allium crameri Asch. & Boiss. | 234 | Medema argum (Mart.) Württemb. ex H.Wendl. | 334 | Centauria scoparia Sieber ex Spreng. | 434 | Picris rhagadioloides (L.) Desf. |
| 35 | Amaranthus tricolor L. | 135 | Allium curtum Boiss. & Gaill. | 235 | Phoenix dactylifera L. | 335 | Centauria sinaica DC. | 435 | Picris strigosa M.Bieb. |
| 36 | Amaranthus viridis L. | 136 | Allium desertorum Forssk. | 236 | Asparagus aphyllus L. | 336 | Centauria solstitialis L. | 436 | Picris sulphurea Delile |
| 37 | Anabasis articulata (Forssk.) Moq. | 137 | Allium erdelyi Zucc. | 237 | Asparagus horridus L. | 337 | Cerua pratensis Forssk. | 437 | Pluchea dioscoridis (L.) DC. |
| 38 | Anabasis prorepens Maire | 138 | Allium longanum Pamp. | 238 | Bellevallia elgii Feinbrun | 338 | Chiliadenus candicans (Delile) Brullo | 438 | Pseudocyniza viscosa (Mill.) D'Arcy |
| 39 | Anabasis setifera Moq. | 139 | Allium mareoticum Bornm. & Gauba | 239 | Bellevallia flexuosa Boiss. | 339 | Chiliadenus montanus (Vahl) Brullo | 439 | Pseudopodopispermum undulatum (Vahl) Zaika, Sukhor. & N.Kilian |
| 40 | Arthrocaulon macrostachyum (Moris.) Pirainen & G.Kaderet | 140 | Allium myrianthum Boiss. | 240 | Bellevallia macrobotrys Boiss. | 340 | Chiliadenus sericeus (Batt. & Trab.) Brullo | 440 | Pulicaria arabica (L.) Cass. |
| 41 | Atriplex canescens (Pursh) Nutt. | 141 | Allium neapolitanum Cirillo | 241 | Bellevallia mauritanica Pomel | 341 | Chlamydomorpha tridentata Ehrenb. ex Less. | 441 | Pulicaria incisa (Lam.) DC. |
| 42 | Atriplex coriacea Forssk. | 142 | Allium orientale Boiss. | 242 | Bellevallia romana (L.) Sweet | 342 | Chrysanthellum indicum DC. | 442 | Pulicaria odora (L.) Rchb. |
| 43 | Atriplex dimorphostegia Kar. & Kir. | 143 | Allium pallens L. | 243 | Bellevallia salah-edidi Täckh. & Boulos | 343 | Cichorium calvum Sch.Bip. | 443 | Pulicaria petiolaris Jaub. & Spach |
| 44 | Atriplex ehrenbergii F.Muell. ex Asch. & Schweinf. | 144 | Allium roseum L. | 244 | Bellevallia sessilifolia (Viv.) Kunth | 344 | Cichorium endivia L. | 444 | Pulicaria sicula (L.) Moris |
| 45 | Atriplex farinosa Forssk. | 145 | Allium sativum L. | 245 | Bellevallia trifoliata (Ten.) Kunth | 345 | Cichorium intybus L. | 445 | Pulicaria undulata (L.) C.A.Mey. |
| 46 | Atriplex glauca L. | 146 | Allium sphaerocephalum L. | 246 | Dipicad erythraeum Webb & Berthel. | 346 | Cichorium pumilum Jacq. | 446 | Pulicaria vulgaris Gaertn. |
| 47 | Atriplex halimus L. | 147 | Allium subhirsutum L. | 247 | Drimia excelsa J.C.Manning & Goldblatt | 347 | Cladanthus mixtus (L.) Chevall. | 447 | Reichardia picroides (L.) Roth |
| 48 | Atriplex holocarpa F.Muell. | 148 | Allium tel-avivense Eig | 248 | Drimia numidica (Jord. & Four.) J.C.Manning & Goldblatt | 348 | Cotula anthemoides L. | 448 | Reichardia tingitana (L.) Roth |
| 49 | Atriplex lindleyi Moq. | 149 | Allium trifoliatum Cirillo | 249 | Drimia palestina M.B.Crespo, Mart.-Azorin & M.A.Alonso | 349 | Crepis aspera L. | 449 | Rhagadiolus stellatus (L.) Gaertn. |
| 50 | Atriplex littoralis L. | 150 | Narcissus tazetta L. | 250 | Drimia purpurascens J.Jacq. | 350 | Crepis clausonis (Pomel) Batt. & Trab. | 450 | Scolymus hispanicus L. |
| 51 | Atriplex nitida Schreb. | 151 | Nothofagus gracile (Aiton) Stearn | 251 | Leopoldia bicolor (Boiss.) Eig & Feinbrun | 351 | Crepis libyca (Pamp.) Bab. | 451 | Scolymus maculatus L. |
| 52 | Atriplex nageiensis Frih. & M.G.Gilbert | 152 | Pancratium arabicum Sickenb. | 252 | Leopoldia comosa (L.) Parl. | 352 | Crepis micrantha Crep. | 452 | Scorzonera schweinfurthii Boiss. |
| 53 | Atriplex nummularia Lindl. | 153 | Pancratium maritimum L. | 253 | Leopoldia eburnea Eig & Feinbrun | 353 | Crepis nigricans Viv. | 453 | Scorzonoides lacinata (Bertol.) Greuter |
| 54 | Atriplex patula L. | 154 | Pancratium sickenbergeri Asch. & Schweinf. | 254 | Muscari albiflorum (Täckh. & Boulos) Hosni | 354 | Crepis sancta (L.) Bornm. | 454 | Scorzonoides simplex (Viv.) Greuter & Talavera |
| 55 | Atriplex portulacoides L. | 155 | Pancratium tortuosum Herb. | 255 | Muscari neglectum Guss. ex Ten. | 355 | Crepis senecioides Delile | 455 | Senecio aegyptius L. |
| 56 | Atriplex prostrata Boucher ex DC. | 156 | Pistacia khinjuk Stocks | 256 | Muscari parviflorum Desf. | 356 | Crocodylion creticum (Boiss. & Heldr.) N.Garcia & Susanna | 456 | Senecio belleyensis Delile |
| 57 | Atriplex rosea L. | 157 | Pistacia lentiscus L. | 257 | Ornithogalum arabicum L. | 357 | Crocodylion pumilio (L.) N.Garcia & Susanna | 457 | Senecio flavus (Decne.) Sch.Bip. |
| 58 | Atriplex semibaccata R.Br. | 158 | Searsia tripartita (Ucria) Moffett | 258 | Ornithogalum narbonneense L. | 358 | Crupina crupinastrum (Moris) Vis. | 458 | Senecio glaucus L. |
| 59 | Atriplex tatarica L. | 159 | Ammi majus L. | 259 | Ornithogalum trichophyllum Boiss. | 359 | Cynara cornigera Lindl. | 459 | Senecio vernalis Walld. & Kit. |
| 60 | Atriplex turcomanica (Moq.) Boiss. | 160 | Ammodaucus leucotrichus Coss. | 260 | Scilla peruviana L. | 360 | Daveaua anthemoides Mariz | 460 | Senecio vulgaris L. |
| 61 | Bassia aegyptiaca Turki, El Shayeib & F.Shehata | 161 | Ammoides pusilla (Brot.) Breitr. | 261 | Asphodelus ramosus L. | 361 | Dicoma tomentosa Cass. | 461 | Silybum marianum (L.) Gaertn. |
| 62 | Bassia aegyptiaca Turki, El Shayeib & F.Shehata | 162 | Anethum graveolens L. | 262 | Asphodelus refractus Boiss. | 362 | Dittrichia viscosa (L.) Greuter | 462 | Sonchus asper (L.) Hill |
| 63 | Bassia arabica (Boiss.) Maire & Weiller | 163 | Anthriscus cerefolium (L.) Hoffm. | 263 | Asphodelus multifolius Cav. | 363 | Echinops galealis Schweinf. | 463 | Sonchus macrocarpus Boulos & C.Jeffrey |
| 64 | Bassia eriophora (Schrad.) Asch. | 164 | Apium graveolens L. | 264 | Asphodelus viscidulus Boiss. | 364 | Echinops glaberrimus DC. | 464 | Sonchus maritimus L. |
| 65 | Bassia indica (Wight) A.J.Scott | 165 | Berula erecta (Huds.) Coville | 265 | Achillea fragrantissima (Forssk.) Sch.Bip. | 365 | Echinops spinosissimus Turra | 465 | Sonchus oleraceus L. |
| 66 | Bassia muricata (L.) Asch. | 166 | Bupleurum lancifolium Hornem. | 266 | Achillea maritima (L.) Ehrend. & Y.P.Guo | 366 | Echinops taekholmianus Amin | 466 | Sonchus tenerimus L. |
| 67 | Beta vulgaris L. | 167 | Bupleurum muschleri H.Wolff | 267 | Achillea wilhelmsii K.Koch | 367 | Eclipta prostrata (L.) L. | 467 | Sphaeranthus suaveolens DC. |
| 68 | Caroxylon cyclophyllum (Baker) Akhani & Roalson | 168 | Bupleurum nanum Poir. | 268 | Aetheorhiza bulbosa (L.) Cass. | 368 | Erigeron bonariensis L. | 468 | Sphianthes costata Benth. |
| 69 | Caroxylon galetum (Maire) Akhani & Roalson | 169 | Bupleurum semicompositum L. | 269 | Ageratum conyzoides L. | 369 | Ethulia conyzoides L. | 469 | Symphoricarpon subulatum (Michx.) G.L.Nesom |
| 70 | Caroxylon imbricatum (Forssk.) Moq. | 170 | Bupleurum subvatum Link ex Spreng. | 270 | Ageratum houistanianum Mill. | 370 | Filago contracta (Boiss.) Chrtk & Holub | 470 | Tagetes minuta L. |
| 71 | Caroxylon inerme (Forssk.) Akhani & Roalson | 171 | Carum carvi L. | 271 | Ambrosia artemisiifolia L. | 371 | Filago desertorum Pomel | 471 | Taraxacum minimum (V.Br.) N.Terracc. |
| 72 | Caroxylon jordanicola (Eig) Akhani & Roalson | 172 | Coriandrum sativum L. | 272 | Ambrosia maritima L. | 372 | Filago mareotica Delile | 472 | Taraxacum syriacum Boiss. |
| 73 | Caroxylon spinescens (Moq.) Akhani & Roalson | 173 | Crithmum maritimum L. | 273 | Anacyclus monanthos (L.) Thell. | 373 | Filago prolifera Pomel | 473 | Taraxacum turcicum Soest |
| 74 | Caroxylon tetragonum (Delile) Moq. | 174 | Cuminum cyminum L. | 274 | Anthemis arvensis L. | 374 | Flaveria bidentis (L.) Kuntze | 474 | Tripleurospermum auriculatum (Boiss.) Rech.f. |
| 75 | Caroxylon tetrandrum (Forssk.) Akhani & Roalson | 175 | Cycloperum leptophyllum (Pers.) Sprague | 275 | Anthemis chia L. | 375 | Garhadiolus hedynopsis Jaub. & Spach | 475 | Tussilago farfara L. |
| 76 | Caroxylon villosum (Schult.) Akhani & Roalson | 176 | Daucus aureus Desf. | 276 | Anthemis cotula L. | 376 | Gelasia psychrophila (Boiss. & Hausskn.) Zaika, Sukhor. & N.Kilian | 476 | Urospermum picroides (L.) Scop. ex F.W.Schmidt |
| 77 | Caroxylon volkensii (Schweinf. & Asch.) Akhani & Roalson | 177 | Daucus carota L. | 277 | Anthemis deserti Boiss. | 377 | Geropogon hybridus (L.) Sch.Bip. | 477 | Verbesina encelioides (Cav.) Benth. & Hook.f. ex A.Gray |
| 78 | Chenopodiaceum murale (L.) S.Fuentes, Uotila & Borsch | 178 | Daucus glaber (Forssk.) Thell. | 278 | Anthemis fayadina Zareh | 378 | Glebionis coronaria (L.) Cass. ex Spach | 478 | Voluntaria crupinoides (Desf.) Maire |
| 79 | Chenopodia anonyma Moq. | 179 | Daucus guttatus Sm. | 279 | Anthemis idraulone Delile | 379 | Gnaphalium polycaulon Pers. | 479 | Voluntaria lippii Cass. |
| 80 | Chenopodium album L. | 180 | Daucus pumilus (L.) Hoffmanns. & Link | 280 | Anthemis melampodina Delile | 380 | Gnaphalium uliginosum L. | 480 | Voluntaria saharae (L.Chevall.) Wagenitz |
| 81 | Chenopodium ficifolium Sm. | 181 | Daucus sylvicus Murb. | 281 | Anthemis muscoperla Boiss. & Kotschy | 381 | Gnomophallum pulvinatum (Delile) Greuter | 481 | Voluntaria sinaica (DC.) Wagenitz |
| 82 | Chenopodium giganteum D.Don | 182 | Deverra tortuosa (Desf.) DC. | 282 | Anthemis pseudocotula Boiss. | 382 | Grangea maderaspatana (L.) Poir. | 482 | Voluntaria tubiflora (Murb.) Sennen |
| 83 | Chenopodium moquianum Aellen | 183 | Deverra triadatiata Hochst. ex Boiss. | 283 | Anthemis retusa Delile | 383 | Gymnarrhena micrantha Desf. | 483 | Xanthium spinosum L. |
| 84 | Chenopodium opulifolium Schrad. ex W.D.J.Koch & Ziz | 184 | Ducrosta ismaelis Asch. | 284 | Anthemis iudaea Eig | 384 | Hedynopsis rhagadioloides (L.) F.W.Schmidt | 484 | Xanthium strumarium L. |
| 85 | Cornulaca ehrenbergii Asch. | 185 | Eryngium campestre L. | 285 | Artemisia absinthium L. | 385 | Helichrysum glumaceum DC. | 485 | Zoegea purpurea Fresen. |
| 86 | Cornulaca monachata Delile | 186 | Eryngium creticum Lam. | 286 | Artemisia annua L. | 386 | Helichrysum luteoalbum (L.) Rchb. | 486 | Leontice leontopetalum L. |
| 87 | Digera muricata (L.) Mart. | 187 | Eryngium glomeratum Lam. | 287 | Artemisia judaea Sieber ex DC. | 387 | Helichrysum orientale (L.) Gaertn. | 487 | Alkanna tinctoria (L.) Tausch |
| 88 | Dysphania ambrosioides (L.) Mosyakin & Clemants | 188 | Eryngium hainesii C.C.Towns. | 288 | Artemisia inculta L. | 388 | Helichrysum stoechas (L.) Moench | 488 | Anchusa acutis Bellardi ex Bertero |
| 89 | Dysphania botrys (L.) Mosyakin & Clemants | 189 | Eryngium tricuspidatum L. | 289 | Artemisia monosperma Delile | 389 | Helminthotheca echioides (L.) Holub | 489 | Anchusa aegyptiaca (L.) A.D.C. |
| 90 | Holocnemum strobilaceum (Pall.) M.Bieb. | 190 | Ferula marmarica Asch. & Taub. | 290 | Artemisia scoparia Waldst. & Kit. | 390 | Heteroderis pusilla (Boiss.) Boiss. | 490 | Anchusa aggregata Lehm. |
| 91 | Haloepilis amplexicaulis (Vahl) Ung.-Sternb. ex Ces., Pass. & Gibelli | 191 | Foeniculum vulgare Mill. | 291 | Artemisia sieberi Besser | 391 | Myoseris lucida L. | 491 | Anchusa hybrida Ten. |
| 92 | Haloepilis perfoliata (Forssk.) Bunge ex Ung.-Sternb. | 192 | Helosciadium nodiflorum (L.) W.D.J.Koch | 292 | Asteriscus aquaticus (L.) Less. | 392 | Myoseris scabra L. | 492 | Anchusa milleri Lam. ex Spreng. |
| 93 | Haloxylon persicum Moq. | 193 | Leiotulus alexandrinus Ehrenb. | 293 | Asteriscus graveolens (Forssk.) Less. | 393 | Illoja spicata (Forssk.) Sch.Bip. | 493 | Arnebia decumbens (Vent.) Coss. & Kralik |
| 94 | Haloxylon salicornicum (Bunge) Bunge ex Boiss. | 194 | Petroselinum crispum (Mill.) Fuss | 294 | Atractylis arvensis Batt. | 394 | Iphiaon mucronata (Forssk.) Asch. & Schweinf. | 494 | Arnebia hispidissima (Sieber ex Lehm.) A.D.C. |
| 95 | Haloxylon scoparium Pomel | 195 | Pimpinella schweinfurthii Asch. | 295 | Atractylis cancellata L. | 395 | Iphiaon scabra DC. ex Decne. | 495 | Arnebia linearifolia A.D.C. |
| 96 | Haloxylon tamariscifolium (L.) Pau | 196 | Scandix pecten-venensis L. | 296 | Atractylis carota (Forssk.) C.Ch. | 396 | Koelipolia linearis Pall. | 496 | Arnebia tinctoria Forssk. |
| 97 | Krascheninikovia ceratoides (L.) Gueldenst. | 197 | Scandix stellata Banks & Sol. | 297 | Atractylis mernepthae Asch. & Schweinf. & Letourn. | 397 | Lactuca orientalis (Boiss.) Boiss. | 497 | Buglossoides arvensis (L.) I.M.Johnst. |
| 98 | Noaea mucronata (Forssk.) Asch. & Schweinf. | 198 | Stolbaria dichotomum (L.) Raf. | 298 | Atractylis prolifera Boiss. | 398 | Lactuca saligna L. | 498 | Buglossoides incrassata (Guss.) I.M.Johnst. |

Table (B) Native Species in Egypt according to Royal Botanic Gardens, Kew, online, Source: RBG Kew, 2021 (Cont'd)

| Nu | Name | Nu | Name | Nu | Name | Nu | Name | Nu | Name |
|-----|--|-----|---|-----|--|-----|---|-----|---|
| 99 | Oureta lanata (L.) Kuntze | 199 | Tordylium aegyptiacum (L.) Poir. | 299 | Attractylis serratuloides Sieber ex Cass. | 399 | Lactuca sativa L. | 499 | Buglossoides tenuiflora (L.f.) I.M.Johnst. |
| 100 | Oxybasis glauca (L.) S.Fuentes, Uotila & Borsch | 200 | Torilis arvensis (Huds.) Link | 300 | Baccharoides schimperii (DC.) Hozumii, G. Ghazaly & B. Nord. | 400 | Lactuca serriola L. | 500 | Coldenia procumbens L. |
| Nu | Name | Nu | Name | Nu | Name | Nu | Name | Nu | Name |
| 501 | Cordia myxa L. | 601 | Morettia philaena (Delile) DC. | 701 | Silene pseudoatocion Desf. | 801 | Cymodocea rotundata Asch. & Schweinf. | 901 | Euphorbia terracina L. |
| 502 | Cordia quercifolia Klotzsch | 602 | Moricandia nitens (Viv.) E.A.Durand & Barratte | 702 | Silene rubella L. | 802 | Halodule uninervis (Forssk.) Boiss. | 902 | Mercurialis annua L. |
| 503 | Cordia sinensis Lam. | 603 | Moricandia sinica (Boiss.) Boiss. | 703 | Silene succulenta Forssk. | 803 | Oceana serrulata (R.Br.) Byng & Christen. | 903 | Ricinus communis L. |
| 504 | Echiochilon fruticosum Desf. | 604 | Nasturtium coronopifolia (Desf.) Boiss. | 704 | Silene tridentata Desf. | 804 | Syringodium isoetifolium (Asch.) Dandy | 904 | Aeschynomene elaphroxylon (Guill. & Perr.) Taub. |
| 505 | Echium angustifolium Mill. | 605 | Nasturtium officinale W.T.Aiton | 705 | Silene villosa Forssk. | 805 | Thalassodendron ciliatum (Forssk.) Hartog | 905 | Aeschynomene pudica F.Dietr. |
| 506 | Echium glomeratum Poir. | 606 | Neotouraria torulosa (Desf.) Hedge & J.Léonard | 706 | Silene vivianii Steud. | 806 | Cynomorium coccineum L. | 906 | Albizia lebbeck (L.) Benth. |
| 507 | Echium horridum Batt. | 607 | Neslia paniculata (L.) Desv. | 707 | Silene vulgaris (Moench) Garcke | 807 | Bolboschoenus glaucus (Lam.) S.G.Sm. | 907 | Albizia procera (Roxb.) Benth. |
| 508 | Echium longifolium Delile | 608 | Notoceras bicorne (Aiton) Am. | 708 | Spergularia bocconei (Scheele) Graebn. | 808 | Carex distans L. | 908 | Albizia schimperiana Oliv. |
| 509 | Echium plantagineum L. | 609 | Ochthodium aegyptiacum (L.) DC. | 709 | Spergularia diandra (Guss.) Heldr. | 809 | Carex divisa Huds. | 909 | Alhagi graecorum Boiss. |
| 510 | Echium rauwolfii Delile | 610 | Pseuderucaria clavata (Boiss. & Reut.) O.E.Schulz | 710 | Spergularia flaccida (Madden) I.M.Turner | 810 | Carex extensa Gooden. | 910 | Anagyris foetida L. |
| 511 | Echium rubrum Forssk. | 611 | Pseuderucaria teretifolia (Desf.) O.E.Schulz | 711 | Spergularia marina (L.) Besser | 811 | Carex pachystylis J.Gay | 911 | Anthyllis circinnata (L.) D.D.Sokoloff |
| 512 | Echium sabulicola Pomel | 612 | Raphanus raphanistrum L. | 712 | Spergularia media (L.) C.Presl | 812 | Cladium mariscus (L.) Pohl | 912 | Anthyllis vulneraria L. |
| 513 | Euploca ovalifolia (Forssk.) Diane & Hilger | 613 | Rapistrum rugosum (L.) All. | 713 | Spergularia rubra (L.) J.Presl & C.Presl | 813 | Cyperus alopecuroides Rottb. | 913 | Argyrobolium arabicum (Decne.) Jaub. & Spach |
| 514 | Gastrocotyle hispida (Forssk.) Bunge | 614 | Rorippa indica (L.) Hiern | 714 | Sphaerocoma hookeri T.Anderson | 814 | Cyperus alternifolius L. | 914 | Argyrobolium saharae Pomel |
| 515 | Heliotropium aegyptiacum Lehm. | 615 | Rorippa micrantha (B.Heyne ex Roth) Jonsell | 715 | Stellaria apetala Ucria | 815 | Cyperus articulatus L. | 915 | Argyrobolium uniflorum (Decne.) Jaub. & Spach |
| 516 | Heliotropium amplexicaule Vahl | 616 | Rorippa palustris (L.) Besser | 716 | Stellaria media (L.) Vill. | 816 | Cyperus capitatus Vand. | 916 | Astragalus annularis Forssk. |
| 517 | Heliotropium arbanense Fresen. | 617 | Savignya parviflora (Delile) Webb | 717 | Telephium sphaerospermum Boiss. | 817 | Cyperus compressus L. | 917 | Astragalus arpilobus Kar. & Kir. |
| 518 | Heliotropium baciferum Forssk. | 618 | Schimpera arabica Hochst. & Steud. | 718 | Ceratophyllum demersum L. | 818 | Cyperus conglomeratus Rottb. | 918 | Astragalus astericus Steven |
| 519 | Heliotropium crispum Desf. | 619 | Schouwibia purpurea (Forssk.) Schweinf. | 719 | Ceratophyllum muricatum Cham. | 819 | Cyperus difformis L. | 919 | Astragalus boeticus L. |
| 520 | Heliotropium curvicaucum L. | 620 | Sinapis alba L. | 720 | Fumana arabica (L.) Spach | 820 | Cyperus digitatus Roxb. | 920 | Astragalus bombycinus Boiss. |
| 521 | Heliotropium digynum (Forssk.) Asch. ex C.Chr. | 621 | Sinapis arvensis L. | 721 | Fumana thymifolia (L.) Webb | 821 | Cyperus dives Delile | 921 | Astragalus caprinus L. |
| 522 | Heliotropium europaeum L. | 622 | Sisymbrium erysimoides Desf. | 722 | Helianthemum aegyptiacum (L.) Mill. | 822 | Cyperus esculentus L. | 922 | Astragalus contortuplicatus L. |
| 523 | Heliotropium hispidissimum Weber | 623 | Sisymbrium irio L. | 723 | Helianthemum crassifolium Pers. | 823 | Cyperus flavescens L. | 923 | Astragalus crenatus Schult. |
| 524 | Heliotropium lasiocarpum Fisch. & C.A.Mey. | 624 | Sisymbrium ramulosum Delile | 724 | Helianthemum kahiriicum Delile | 824 | Cyperus flavidus Retz. | 924 | Astragalus eremophilus Boiss. |
| 525 | Heliotropium pterocarpum (DC.) Hochst. & Steud. ex Bunge | 625 | Zilla spinosa (L.) Prantl | 725 | Helianthemum ledifolium (L.) Mill. | 825 | Cyperus fuscus L. | 925 | Astragalus fruticosus Forssk. |
| 526 | Heliotropium ramosissimum (Lehm.) Sieber ex DC. | 626 | Commiphora quadricincta Schweinf. | 726 | Helianthemum lippii (L.) Dum.Cours. | 826 | Cyperus imbricatus Retz. | 926 | Astragalus hamous L. |
| 527 | Heliotropium rotundifolium Sieber ex Lehm. | 627 | Campanula dimorphantha Schweinf. | 727 | Helianthemum salicifolium (L.) Mill. | 827 | Cyperus jeminicus Rottb. | 927 | Astragalus hispidulus DC. |
| 528 | Heliotropium supinum L. | 628 | Campanula erinus L. | 728 | Helianthemum sancti-antoni Schweinf. ex Boiss. | 828 | Cyperus laevigatus L. | 928 | Astragalus kahiriicus DC. |
| 529 | Lappula spinocarpus (Forssk.) Asch. ex Kuntze | 629 | Campanula sulphurea Boiss. | 729 | Helianthemum schweinfurthii Grosser | 829 | Cyperus longus L. | 929 | Astragalus kralikii Coss. ex Batt. |
| 530 | Microparacaryum bungei (Boiss.) Khat. | 630 | Legousia speculum-veneris (L.) Chaix | 730 | Helianthemum stipulatum (Forssk.) C.Chr. | 830 | Cyperus macrorrhizus Nees | 930 | Astragalus mareoticus Delile |
| 531 | Microparacaryum intermedium (Fresen.) Hilger & Rodich. | 631 | Wahlenbergia campanuloides (Delile) Vatke | 731 | Helianthemum ventosum Boiss. | 831 | Cyperus maculatus Boeckeler | 931 | Astragalus peregrinus Vahl |
| 532 | Moltikopsis ciliata (Forssk.) I.M.Johnst. | 632 | Wahlenbergia lobeloides (L.f.) Link | 732 | Helianthemum vesicarium Boiss. | 832 | Cyperus michelianus (L.) Delile | 932 | Astragalus pseudosinicus Gazer & Podlech |
| 533 | Nonea melanocarpa Boiss. | 633 | Cadaba farinosa Forssk. | 733 | Helianthemum virgatum (Desf.) Pers. | 833 | Cyperus mundi (Nees) Kunth | 933 | Astragalus schimperii Boiss. |
| 534 | Nonea vivianii DC. | 634 | Cadaba rotundifolia Forssk. | 734 | Cleome amblyocarpa Barratte & Murb. | 834 | Cyperus papyrus L. | 934 | Astragalus sieberi DC. |
| 535 | Ogastemma pusillum (Coss. & Duran) ex Barmst. & Barratte (Barmst.) | 635 | Capparis cartilaginea Decne. | 735 | Cleome arabica L. | 835 | Cyperus polystachyos Rottb. | 935 | Astragalus spinosus (Forssk.) Muschl. |
| 536 | Podonosma galatensis Schweinf. ex Boiss. | 636 | Capparis decidua (Forssk.) Edgew. | 736 | Cleome brachycarpa Vahl ex DC. | 836 | Cyperus procerus Rottb. | 936 | Astragalus stella L. |
| 537 | Trichodesma africanum (L.) Sm. | 637 | Capparis spinosa L. | 737 | Cleome chrysantha Decne. | 837 | Cyperus rotundus L. | 937 | Astragalus tribuloides Delile |
| 538 | Trichodesma hirsutissimum Schweinf. | 638 | Maerua crassifolia Forssk. | 738 | Cleome drosierifolia (Forssk.) Delile | 838 | Cyperus schimperianus Steud. | 938 | Astragalus trigonus DC. |
| 539 | Alyssum collinum Brot. | 639 | Cephalaria syriaca (L.) Schrad. | 739 | Cleome gynandra L. | 839 | Eleocharis caduca (Delile) Schult. | 939 | Astragalus trimestris L. |
| 540 | Alyssum desertorum Stapf | 640 | Lomelosia palestina (L.) Raf. | 740 | Cleome pallida Kotschy | 840 | Eleocharis geniculata (L.) Roem. & Schult. | 940 | Astragalus vogelii (Webb) Borm. |
| 541 | Arabis caucasica Willd. | 641 | Pterocarpus brevis Coult. | 741 | Cleome paradoxa R.Br. ex DC. | 841 | Eleocharis palustris (L.) Roem. & Schult. | 941 | Biserrula epiglottis (L.) Coult. & Rabatte & J.-M.Tison |
| 542 | Arabis engleriana Muschl. | 642 | Pterocarpus plumosus (L.) Coult. | 742 | Cleome scaposa DC. | 842 | Eleocharis parvula (Roem. & Schult.) Link ex Barmst. & Schauer | 942 | Caesalpinia pulcherrima (L.) Sw. |
| 543 | Biscutella didyma L. | 643 | Scabiosa arenaria Forssk. | 743 | Cleome viscosa L. | 843 | Eleocharis quinqueflora (Hartmann) O.Schwarz | 943 | Cajanus cajan (L.) Huith |
| 544 | Brassica juncea (L.) Czern. | 644 | Scabiosa eremophila Boiss. | 744 | Colchicum gramineum (Cav.) J.C.Manning & Vinn. | 844 | Fimbristylis bisumbellata (Forssk.) Bubani | 944 | Cassia eremophila A.Cunn. ex Vogel |
| 545 | Brassica nigra (L.) W.D.J.Koch | 645 | Valeriana calitrapae L. | 745 | Colchicum palestinum (Baker) C.Archer | 845 | Fimbristylis ferruginea (L.) Vahl | 945 | Cassia fistula L. |
| 546 | Brassica rapa L. | 646 | Valeriana discoides (L.) Willd. | 746 | Colchicum ritchii R.Br. | 846 | Fimbristylis turkestanica (Regel) B.Fedtsch. | 946 | Cicer arietinum L. |
| 547 | Cakile maritima Scop. | 647 | Valeriana slovianica (Fisch. & C.A.Mey.) Chrenk. & Byng | 747 | Colchicum schimperii Janka ex Stef. | 847 | Fuirena ciliaris (L.) Roxb. | 947 | Cicer cuneatum Hochst. ex A.Rich. |
| 548 | Camelina hispida Boiss. | 648 | Valeriana benghalensis L. | 748 | Commelina benghalensis L. | 848 | Fuirena pubescens (Poir.) Kunth | 948 | Cilitoria ternatea L. |
| 549 | Camelina rumelica Velen. | 649 | Arenaria serpyllifolia L. | 749 | Commelina boissieriana C.B.Clarke | 849 | Isolepis setacea (L.) R.Br. | 949 | Coronilla scorpioides (L.) W.D.J.Koch |
| 550 | Capella bursa-pastoris (L.) Medik. | 650 | Atocion armeria (L.) Raf. | 750 | Commelina forskaellii Vahl | 850 | Schoenoplectiella articulata (L.) Lye | 950 | Coronilla securida L. |
| 551 | Carrichtera annua (L.) DC. | 651 | Cometes abyssinica R.Br. ex Wall. | 751 | Calyptegia silvatica (Kit.) Griseb. | 851 | Schoenoplectiella erecta (Poir.) Lye | 951 | Crotalaria aegyptiaca Benth. |
| 552 | Coincya tournefortii (Gouan) | 652 | Dianthus cyri Fisch. & C.A.Mey. | 752 | Convolvulus althaeoides L. | 852 | Schoenoplectiella mucronata (L.) J.Jung & H.K.Choi | 952 | Crotalaria microphylla Vahl |
| 553 | Conringia orientalis (L.) C.Presl | 653 | Dianthus gussfeldtianus Muschl. | 753 | Convolvulus arvensis L. | 853 | Schoenoplectiella senegalensis (Steud.) Lye | 953 | Crotalaria thebaica (Delile) DC. |
| 554 | Cupressella homalocarpa (Fisch. & C.A.Mey.) | 654 | Eremogone picta (Sm.) Dillenb. & Kadereit | 754 | Convolvulus dorycnium L. | 854 | Schoenoplectiella supina (L.) Lye | 954 | Cullen plicatum (Delile) C.H.Stirt. |
| 555 | Descurainia sophia (L.) Webb ex Prantl | 655 | Gymnocarpus decander Forssk. | 755 | Convolvulus pinnatus Kunze | 855 | Schoenoplectus corymbosus (Hochst. ex Barmst. & Schult.) J.Raynal | 955 | Delonix elata (L.) Gamble |
| 556 | Dichasanthus runcinatus (Lag. ex DC.) V.J.Dorof. | 656 | Gymnocarpus sclerocarpus (Decne.) Dahlgren & Thulin | 756 | Convolvulus glomeratus Choisy | 856 | Schoenoplectus subulatus (Vahl) Lye | 956 | Delonix regia (Bojer ex Hook.) Raf. |
| 557 | Didesmus aegyptiacus (L.) Desv. | 657 | Gypsophila capillaris (Forssk.) C.Chr. | 757 | Convolvulus humilis Jacq. | 857 | Schoenoplectus triquetus (L.) Palla | 957 | Dichrostachys cinerea (L.) Wight & Arn. |
| 558 | Didesmus bipinnatus (Desf.) DC. | 658 | Gypsophila vaccaria (L.) Sm. | 758 | Convolvulus hystrix Vahl | 858 | Scirpoides holoschoenus (L.) Soják | 958 | Ebenus armitagei Schweinf. & Taub. |
| 559 | Diplotaxis acris (Forssk.) Boiss. | 659 | Herniaria cinerea (L.) DC. | 759 | Convolvulus lanatus Vahl | 859 | Pteridium aquilinum (L.) Kuhn | 959 | Erythrina crista-galli L. |
| 560 | Diplotaxis erucoides (L.) DC. | 660 | Herniaria cyrenica F.Herm. | 760 | Convolvulus lineatus L. | 860 | Euclea racemosa L. | 960 | Erythrina speciosa Andrews |
| 561 | Diplotaxis harra (Forssk.) Boiss. | 661 | Herniaria fontanesii J.Gay | 761 | Convolvulus oleifolius Desr. | 861 | Bergia ammannioides Roxb. | 961 | Erythrina variegata L. |
| 562 | Diplotaxis muralis (L.) DC. | 662 | Herniaria hemistemon J.Gay | 762 | Convolvulus pilosellifolius Desr. | 862 | Bergia capensis L. | 962 | Faidherbia albida (Delile) A.Chev. |
| 563 | Diplotaxis simplex (Viv.) Spreng. | 663 | Herniaria hirsuta L. | 763 | Convolvulus prostratus Forssk. | 863 | Bergia suffruticosa (Delile) Fenzl | 963 | Genista aegyptiaca Spreng. |
| 564 | Diplotaxis x schweinfurthii O.E.Schulz | 664 | Herniaria lenticalata Forssk. | 764 | Convolvulus rhytismus Hochst. ex Choisy | 864 | Elatine macropoda Guss. | 964 | Gynce moringifolia Delile |
| 565 | Enarthrocarpus lyrtus (Forssk.) DC. | 665 | Loeflingia hispanica L. | 765 | Convolvulus scandens Delile | 865 | Ephedra alata Decne. | 965 | Glycyrrhiza glabra L. |
| 566 | Enarthrocarpus pterocarpus (Pers.) DC. | 666 | Paronychia arabica (L.) DC. | 766 | Convolvulus siculus L. | 866 | Ephedra aphylla Forssk. | 966 | Guilandina bonduc L. |
| 567 | Enarthrocarpus stragulatus Boiss. | 667 | Paronychia argentea Lam. | 767 | Convolvulus stachydfolius Choisy | 867 | Ephedra ciliata Fisch. & C.A.Mey. | 967 | Haematoxylum campechianum L. |
| 568 | Eremobolus aegyptiacum (Spreng.) Asch. ex Boiss. | 668 | Paronychia capitata (L.) Lam. | 768 | Cressa cretica L. | 868 | Chrozophora brocciana Vis. | 968 | Hippocrepis aereolata Desv. |
| 569 | Erucaria crassifolia (Forssk.) Delile | 669 | Paronychia sinica Fresen. | 769 | Cuscuta approximata Bab. | 869 | Chrozophora plicata (Vahl) A.Juss. ex Spreng. | 969 | Hippocrepis biflora Spreng. |
| 570 | Erucaria hispanica (L.) Druce | 670 | Petrorhagia illyrica (Ard.) P.W.Ball & Heywood | 770 | Cuscuta brevistyla A.Braun ex A.Rich. | 870 | Chrozophora tinctoria (L.) A.Juss. | 970 | Hippocrepis constricta Kunze |
| 571 | Erucaria microcarpa Boiss. | 671 | Polycarpha repens (Forssk.) Asch. & Schweinf. | 771 | Cuscuta campestris Yunk. | 871 | Euphorbia arabica Hochst. & Steud. ex T.Anderson | 971 | Hippocrepis cyclocarpa Murb. |
| 572 | Erucaria pinnata (Viv.) Täckh. & Boulos | 672 | Polycarpha roborensis (Kuntze) Greuter & Burdet | 772 | Cuscuta epilimum Weihe | 872 | Euphorbia arguta Banks & Sol. | 972 | Hippocrepis uniliquosa L. |
| 573 | Erucastum arabicum Fisch. & C.A.Mey. | 673 | Polycarpha spicata Wight ex Arn. | 773 | Cuscuta monogyna Vahl | 873 | Euphorbia bivonae Steud. | 973 | Indigofera argentea Burm.f. |
| 574 | Erucaria vesicaria (L.) Cav. | 674 | Polycarpon alsinifolium (Biv.) DC. | 774 | Cuscuta palestina Boiss. | 874 | Euphorbia chamaepeplus Boiss. & Gaill. | 974 | Indigofera articulata Gouan |
| 575 | Erysimum cheiranthoides L. | 675 | Polycarpon prostratum (Forssk.) Asch. & Schweinf. | 775 | Cuscuta pedicellata Ledeb. | 875 | Euphorbia chamaeyce L. | 975 | Indigofera coerulescens Roxb. |
| 576 | Erysimum repandum L. | 676 | Polycarpon succulentum J.Gay | 776 | Cuscuta planiflora Ten. | 876 | Euphorbia cuneata Vahl | 976 | Indigofera colutea (Burm.f.) Merr. |
| 577 | Farselia aegyptia Turra | 677 | Polycarpon tetraphyllum (L.) L. | 777 | Dichondra micrantha Urb. | 877 | Euphorbia dendroides L. | 977 | Indigofera cordifolia B.Heyne ex Roth |
| 578 | Farselia longisiliqua Decne. | 678 | Pteranthus dichotomus Forssk. | 778 | Ipomoea batatas (L.) Lam. | 878 | Euphorbia dracunculoides Lam. | 978 | Indigofera dendroica Schrank |
| 579 | Farselia stylosa R.Br. | 679 | Rhodalsine geniculata (Poir.) F.N.Williams | 779 | Ipomoea biflora (L.) Pers. | 879 | Euphorbia exigua L. | 979 | Indigofera hochstetteri Baker |
| 580 | Fibula clypeata (L.) Medik. | 680 | Sabulina mediterranea (Ledeb. ex Link) Rchb. | 780 | Ipomoea calrica (L.) Sweet | 880 | Euphorbia falcata L. | 980 | Indigofera lotononoides Baker f. |
| 581 | Hornungia procumbens (L.) Hayek | 681 | Sabulina tenuifolia (L.) Rchb. | 781 | Ipomoea carnea Jacq. | 881 | Euphorbia forskaellii J.Gay | 981 | Indigofera oblongifolia Forssk. |
| 582 | Isatis lusitana L. | 682 | Silene aegyptiaca (L.) L.f. | 782 | Ipomoea ericarpa R.Br. | 882 | Euphorbia granulata Forssk. | 982 | Indigofera sessiliflora DC. |
| 583 | Isatis microcarpa J.Gay ex Boiss. | 683 | Silene alexandrina (Asch.) Danin | 783 | Ipomoea hederacea Jacq. | 883 | Euphorbia grossheimii (Prokh.) Prokh. | 983 | Indigofera spiniflora Hochst. ex Boiss. |
| 584 | Lepidium aucheri Boiss. | 684 | Silene apetala Willd. | 784 | Ipomoea heptaphylla Sweet | 884 | Euphorbia helioscopia L. | 984 | Indigofera spinosa Forssk. |
| 585 | Lepidium coronopus (L.) Al-Shehbaz | 685 | Silene arabica Boiss. | 785 | Ipomoea imperati (Vahl) Griseb. | 885 | Euphorbia hierosolymitana Boiss. | 985 | Lathyrus annuus L. |
| 586 | Lepidium didymum L. | 686 | Silene behen L. | 786 | Ipomoea pes-caprae (L.) R.Br. | 886 | Euphorbia inaequaliterna Sond. | 986 | Lathyrus aphaca L. |
| 587 | Lepidium draba L. | 687 | Silene biapiculata Ehrh. ex Rohrb. | 787 | Ipomoea purpurea (L.) Roth | 887 | Euphorbia maculata L. | 987 | Lathyrus hierosolymitanus Boiss. |
| 588 | Lepidium latifolium L. | 688 | Silene chirensis A.Rich. | 788 | Ipomoea triloba L. | 888 | Euphorbia rubica N.E.Br. | 988 | Lathyrus hirsutus L. |
| 589 | Lepidium niloticum (Delile) Sieber | 689 | Silene colorata Poir. | 789 | Seddera arabica (Forssk.) Choisy | 889 | Euphorbia oxyodonata Boiss. | 989 | Lathyrus marmoratus Boiss. & Balansa |
| 590 | Lepidium sativum L. | 690 | Silene confilora Nees ex Oth | 790 | Seddera latifolia Hochst. & Steud. | 890 | Euphorbia paralias L. | 990 | Lathyrus oleraceus Lam. |
| 591 | Leptaleum filifolium (Willd.) DC. | 691 | Silene conoidea L. | 791 | Crassula alata (Viv.) A.Berger | 891 | Euphorbia parvula Delile | 991 | Lathyrus pseudocicera Pamp. |
| 592 | Lobularia arabica (Boiss.) Muschl. | 692 | Silene elongata Forssk. ex Steud. | 792 | Umbilicus horizontalis (Guss.) DC. | 892 | Euphorbia pepilis L. | 992 | Lathyrus sativus L. |
| 593 | Lobularia illyrica (Viv.) Meisn. | 693 | Silene forskohlei Steud. | 793 | Umbilicus intermedius Boiss. | 893 | Euphorbia pepulus L. | 993 | Lathyrus setifolius L. |
| 594 | Lobularia maritima (L.) Desv. | 694 | Silene fruticosa L. | 794 | Bryonia cretica L. | 894 | Euphorbia petiolata Banks & Sol. | 994 | Lathyrus sphaericus Retz. |
| 595 | Malcolmia pygmaea (DC.) Boiss. | 695 | Silene gallica L. | 795 | Citrullus colocynthis (L.) Schrad. & Nakai | 895 | Euphorbia polycantha Boiss. | 995 | Leobordea platycarpa (Viv.) B.-E.van Wyk & Boatwr. |
| 596 | Maresia nana (DC.) Batt. | 696 | Silene linearis Decne. | 796 | Citrullus lanatus (Thunb.) Matsum. & Nakai | 896 | Euphorbia punctata Delile | 996 | Leucaena leucocephala (Lam.) de Wit |
| 597 | Matthiola fruticulosa (L.) Maire | 697 | Silene longipetala Vent. | 797 | Coccinia grandis (L.) Voigt | 897 | Euphorbia retusa Forssk. | 997 | Lotus angustissimus L. |
| 598 | Matthiola longipetala (Vent.) DC. | 698 | Silene nocturna L. | 798 | Cucumis melo L. | 898 | Euphorbia scordifolia Jacq. | | |

Table (B) Native Species in Egypt according to Royal Botanic Gardens, Kew, online, Source: RBG Kew, 2021 (Cont'd)

| Nu | Name | Nu | Name | Nu | Name | | | | |
|------|---|------|---|------|---|------|---|------|--|
| 1001 | Lotus creticus L. | 1101 | Trifolium repens L. | 1201 | Lavandula multifida L. | 1301 | Glinus lotoides L. | 1401 | Plantago altissima L. |
| 1002 | Lotus cytoides L. | 1102 | Trifolium pubescens Decne. | 1202 | Lavandula pubescens Decne. | 1302 | Glinus runkwitzii Täckh. & Boulos | 1402 | Plantago amplexicaulis Cav. |
| 1003 | Lotus edulis L. | 1103 | Trifolium scabrum L. | 1203 | Lavandula saharia Upson & Jury | 1303 | Ficus carica L. | 1403 | Plantago ciliata Desf. |
| 1004 | Lotus garcinii Ser. | 1104 | Trifolium stellatum L. | 1204 | Leucas inflata Benth. | 1304 | Ficus palmata Forssk. | 1404 | Plantago coronopus L. |
| 1005 | Lotus gebelii Vent. | 1105 | Trifolium tomentosum L. | 1205 | Leucas neufleazeana Courbon | 1305 | Ficus salicifolia Vahl | 1405 | Plantago crassifolia Forssk. |
| 1006 | Lotus glinoides Delile | 1106 | Trigonella anguina Delille | 1206 | Marrubium alysson L. | 1306 | Ficus sycomorus L. | 1406 | Plantago crypsoides Boiss. |
| 1007 | Lotus halophyllus Boiss. & Spruner | 1107 | Trigonella arabica Delille | 1207 | Mentha longifolia (L.) L. | 1307 | Moringa peregrina (Forssk.) Fiori | 1407 | Plantago cylindrica Forssk. |
| 1008 | Lotus hebranicus Hochst. ex Brand | 1108 | Trigonella berythina Boiss. & C.J. Blanche | 1208 | Mentha pulegiola L. | 1308 | Neurada procumbens L. | 1408 | Plantago exigua Murray |
| 1009 | Lotus nubicus Hochst. ex Baker | 1109 | Trigonella cylindracea Desv. | 1209 | Mentha spicata L. | 1309 | Nitiraria retusa (Forssk.) Asch. | 1409 | Plantago indica L. |
| 1010 | Lotus ornithopodioides L. | 1110 | Trigonella glabra Thunb. | 1210 | Mentha x piperita L. | 1310 | Peganum harmala L. | 1410 | Plantago lagopus L. |
| 1011 | Lotus palustris Willd. | 1111 | Trigonella lacinata L. | 1211 | Micromeria nervosa (Desf.) Benth. | 1311 | Tetradiclis tenella (Ehrenb.) Litv. | 1411 | Plantago lanceolata L. |
| 1012 | Lotus pedunculatus Cav. | 1112 | Trigonella maritima Delille ex Poir. | 1212 | Ocimum forskolei Benth. | 1312 | Boerhavia coccinea Mill. | 1412 | Plantago major L. |
| 1013 | Lotus peregrinus L. | 1113 | Trigonella media Delille ex Urb. | 1213 | Orthosiphon pallidus Royle ex Benth. | 1313 | Boerhavia diandra L. | 1413 | Plantago notata Lag. |
| 1014 | Lotus polyphyllus E.D. Clarke | 1114 | Trigonella occulta Delille ex Ser. | 1214 | Otostegia fruticosa (Forssk.) Schweinf. ex Persig. | 1314 | Boerhavia diffusa L. | 1414 | Plantago ovata Forssk. |
| 1015 | Lotus tenuis Waldst. & Kit. ex Willd. | 1115 | Trigonella stellata Forssk. | 1215 | Philomis floccosa D. Don | 1315 | Boerhavia repens L. | 1415 | Plantago phaeostoma Boiss. & Heldr. |
| 1016 | Lotus tetragonolobus L. | 1116 | Trigonella x schweinfurthiana Muschl. | 1216 | Prasium majus L. | 1316 | Commicarpus helenae (Roem. & Schult.) Meikle | 1416 | Plantago squarrosa Murray |
| 1017 | Lupinus albus L. | 1117 | Trigonella x sickenbergiana Muschl. | 1217 | Pseudodictamnus damascenus (Boiss.) Lohani & Stadel | 1317 | Nymphaea lotus L. | 1417 | Plantago weldenii Rchb. |
| 1018 | Lupinus angustifolius L. | 1118 | Tripodion tetraphyllum (L.) Fourr. | 1218 | Pseudodictamnus mediterraneus Salimaki & Stadel | 1318 | Nymphaea micrantha Guill. & Perr. | 1418 | Veronica anagallis-aquatica L. |
| 1019 | Lupinus digitatus Forssk. | 1119 | Vachellia etbaica (Schweinf.) Kyal. & Boatw. | 1219 | Salvia aegyptiaca L. | 1319 | Nymphaea nouchali Burm.f. | 1419 | Veronica anagallides Guss. |
| 1020 | Medicago arabica (L.) Huds. | 1120 | Vachellia flava (Forssk.) Kyal. & Boatw. | 1220 | Salvia lanigera Poir. | 1320 | Olea europaea L. | 1420 | Veronica beccabunga L. |
| 1021 | Medicago coronata (L.) Bartal. | 1121 | Vachellia nilotica (L.) P.J.H. Hurter & Mabb. | 1221 | Salvia palestina Benth. | 1321 | Epilobium hirsutum L. | 1421 | Veronica catenata Pennell |
| 1022 | Medicago granadensis Willd. | 1122 | Vachellia oerfota (Forssk.) Kyal. & Boatw. | 1222 | Salvia rosmarinus Spenn. | 1322 | Ludwigia adscendens (L.) H. Hara | 1422 | Veronica persica Poir. |
| 1023 | Medicago hypogaea E. Small | 1123 | Vachellia seyal (Delille) P.J.H. Hurter | 1223 | Salvia spinosa L. | 1323 | Ludwigia erecta (L.) H. Hara | 1423 | Veronica polita Fr. |
| 1024 | Medicago intertexta (L.) Mill. | 1124 | Vachellia tortilis (Forssk.) Galasso & Banfi | 1224 | Salvia verbenaca L. | 1324 | Oenothera drummondii Hook. | 1424 | Veronica scardica Griseb. |
| 1025 | Medicago lacinata (L.) Mill. | 1125 | Vicia articulata Hornem. | 1225 | Stachys aegyptiaca Pers. | 1325 | Ophioglossum polyphyllum A. Braun ex Seub. | 1425 | Veronica syriaca Roem. & Schult. |
| 1026 | Medicago littoralis Rohde ex Loisel. | 1126 | Vicia ervilia (L.) Willd. | 1226 | Teucrium brevifolium Schreb. | 1326 | Epipactis veratrifolia Boiss. & Hohen. | 1426 | Limonium guyanicum Durieu ex Boiss. |
| 1027 | Medicago lupulina L. | 1127 | Vicia hirsuta (L.) Gray | 1227 | Teucrium decalaisei C. Presl | 1327 | Bellardia trixago (L.) All. | 1427 | Limonium monoptetum (L.) Boiss. |
| 1028 | Medicago marina L. | 1128 | Vicia hybrida L. | 1228 | Teucrium leucodadum Boiss. | 1328 | Cistanche phelypaea (L.) Cout. | 1428 | Limonium awei (De Not.) Brullo & Erben |
| 1029 | Medicago minima (L.) Bartal. | 1129 | Vicia lutea L. | 1229 | Thymra capitata (L.) Cav. | 1329 | Cistanche tubulosa (Schenk) Wight ex Hook.f. | 1429 | Limonium axillare (Forssk.) Kuntze |
| 1030 | Medicago monspeliaca (L.) Trautv. | 1130 | Vicia monantha Retz. | 1230 | Thymus bovei Benth. | 1330 | Lindenbergia indica (L.) Vathe | 1430 | Limonium bordouellei (T. Lestib.) Kuntze |
| 1031 | Medicago orbicularis (L.) Bartal. | 1131 | Vicia narbonensis L. | 1231 | Vitex agnus-castus L. | 1331 | Orobanchae aegyptiaca Pers. | 1431 | Limonium echiodides (L.) Mill. |
| 1032 | Medicago pedunculata Ehrenb. ex Sweet | 1132 | Vicia parviflora Cav. | 1232 | Volkameria acerbiata Vis. | 1332 | Orobanchae cernua Loeffl. | 1432 | Limonium lobatum (L.f.) Chaz. |
| 1033 | Medicago polycrateria (L.) Sauvages ex Trautv. | 1133 | Vicia peregrina L. | 1233 | Utricularia globa L. | 1333 | Orobanchae crenata Forssk. | 1433 | Limonium narbonense Mill. |
| 1034 | Medicago polymorpha L. | 1134 | Vicia sativa L. | 1234 | Utricularia inflexa Forssk. | 1334 | Orobanchae grisebachii Reut. | 1434 | Limonium pruinosum (L.) Chaz. |
| 1035 | Medicago rigida (L.) All. | 1135 | Vicia serratifolia Jacq. | 1235 | Gagea dayana Chodat & Beauverd | 1335 | Orobanchae lavandulacea Rchb. | 1435 | Limonium scoparium (Pall. ex Willd.) Stankov |
| 1036 | Medicago sativa L. | 1136 | Vicia tetrasperma (L.) Schreb. | 1236 | Gagea reticulata (Pall.) Schult. & Schult.f. | 1336 | Orobanchae minor Sm. | 1436 | Limonium sinuatum (L.) Gaertn. |
| 1037 | Medicago truncatula Gaertn. | 1137 | Vicia villosa Roth | 1237 | Gagea rigida Boiss. & Spruner | 1337 | Orobanchae mutellii F.W. Schultz | 1437 | Limonium tubiflorum (Delille) Kuntze |
| 1038 | Medicago turbinata (L.) All. | 1138 | Vigna luteola (Jacq.) Benth. | 1238 | Tulipa biflora Pall. | 1338 | Orobanchae nana Noë ex Rchb. | 1438 | Limonium zanonii (Pamp.) Domina |
| 1039 | Melilotus albus Medik. | 1139 | Vigna unguiculata (L.) Walp. | 1239 | Unium decumbens Desf. | 1339 | Orobanchae portulicantia A. Pujadas & M.B. Crespo | 1439 | Statice boissieri Lafont |
| 1040 | Melilotus elegans Salzm. ex Ser. | 1140 | Frankenia hirsuta L. | 1240 | Unium pubescens Banks & Sol. | 1340 | Orobanchae pubescens d'Urv. | 1440 | Achnatherum parviflorum (Desf.) M. Nobis |
| 1041 | Melilotus indicus (L.) All. | 1141 | Frankenia pulverulenta L. | 1241 | Unium strictum L. | 1341 | Orobanchae ramosa L. | 1441 | Acrachne racemosa (B. Heyne ex Roth) Ohwi |
| 1042 | Melilotus segetalis (Brot.) Ser. | 1142 | Centaurium maritimum (L.) Fritsch | 1242 | Unium ustatissimum L. | 1342 | Orobanchae schultzei Mutel | 1442 | Aegilops bicornis (Forssk.) Jaub. & Spach |
| 1043 | Melilotus serratifolius Täckh. & Boulos | 1143 | Centaurium pulchellum (Sw.) Hayek ex Hand.-Mazz. Steudim., Janch. & Fatis | 1243 | Lindernia parviflora (Roxb.) Haines | 1343 | Orobanchae schweinfurthii Beck | 1443 | Aegilops geniculata Roth |
| 1044 | Melilotus siculus (Turra) Steud. | 1144 | Centaurium tenuiflorum (Hoffmanns. & Link) Fritsch | 1244 | Plicosepalus curviflorus (Benth. ex Oliv.) Tiegh. | 1344 | Parentucellia viscosa (L.) Caruel | 1444 | Aegilops kotschyii Boiss. |
| 1045 | Mimosa catalpa (L.) Lam. | 1145 | Schenkia spicata (L.) G. Mans. | 1245 | Ammannia aegyptiaca Willd. | 1345 | Striga asiatica (L.) Kuntze | 1445 | Aegilops longissima Schweinf. & Muschl. |
| 1046 | Mimosa pigra L. | 1146 | Erodium arborecens (Desf.) Willd. | 1246 | Ammannia auriculata Willd. | 1346 | Striga gesnerioides (Willd.) Vathe | 1446 | Aegilops peregrina (Hack.) Maire & Weiller |
| 1047 | Onobrychis crista-galli (L.) Lam. | 1147 | Erodium chium (L.) Willd. | 1247 | Ammannia bacifera L. | 1347 | Striga hermonthica (Delille) Benth. | 1447 | Aegilops ventricosa Tausch |
| 1048 | Onobrychis ptolemaica (Delille) DC. | 1148 | Erodium ciconium (L.) L'Hér. | 1248 | Ammannia multiflora Roxb. | 1348 | Oxalis corniculata L. | 1448 | Aeluropus lagopoides (L.) Thwaites |
| 1049 | Ononis diffusa Ten. | 1149 | Erodium cicutarium (L.) L'Hér. | 1249 | Ammannia senegalensis Lam. | 1349 | Oxalis pes-caprae L. | 1449 | Aeluropus littoralis (Gouan) Parl. |
| 1050 | Ononis mitissima L. | 1150 | Erodium crassifolium L'Hér. | 1250 | Lawsania inermis L. | 1350 | Argemone mexicana L. | 1450 | Agropyron cristatum (L.) Gaertn. |
| 1051 | Ononis natrix L. | 1151 | Erodium glaucophyllum (L.) L'Hér. | 1251 | Lythrum hyssopifolia L. | 1351 | Fumaria bracteosa Pomel | 1451 | Alopecurus myosuroides Huds. |
| 1052 | Ononis reclinata L. | 1152 | Erodium gruinum (L.) L'Hér. | 1252 | Lythrum junceum Banks & Sol. | 1352 | Fumaria capreolata L. | 1452 | Ammochloa palestina Boiss. |
| 1053 | Ononis serrata Forssk. | 1153 | Erodium laciniatum (Cav.) Willd. | 1253 | Lythrum thymifolia L. | 1353 | Fumaria densiflora DC. | 1453 | Andropogon ramosus Forssk. |
| 1054 | Ononis sicula Guss. | 1154 | Erodium malacoides (L.) L'Hér. | 1254 | Lythrum tribracteatum Salzm. ex Spreng. | 1354 | Fumaria gallardotii Boiss. | 1454 | Aspera spica-venti (L.) P. Beauv. |
| 1055 | Ononis vaginalis Vahl | 1155 | Erodium moschatum (L.) L'Hér. | 1255 | Abelmoschus esculentus (L.) Moench | 1355 | Fumaria judaica Boiss. | 1455 | Aristida adscensionis L. |
| 1056 | Ononis variegata L. | 1156 | Erodium neuradifolium Delille ex Godr. | 1256 | Abutilon bidentatum Hochst. ex A. Rich. | 1356 | Fumaria microstachys Kralkik ex Hausskn. | 1456 | Aristida fuciculata Trin. & Rupr. |
| 1057 | Pithecollobium dulce (Roxb.) Benth. | 1157 | Erodium oxyrhynchum M. Bieb. | 1257 | Abutilon erythraeum Mattei | 1357 | Fumaria officinalis L. | 1457 | Aristida mutabilis Trin. & Rupr. |
| 1058 | Pongamia pinnata (L.) Pierre | 1158 | Erodium pulverulentum (Cav.) Willd. | 1258 | Abutilon fruticosum Guill. & Perr. | 1358 | Fumaria parviflora Lam. | 1458 | Arundo donax L. |
| 1059 | Prosopis farcta (Banks & Sol.) J.F. Macbr. | 1159 | Erodium salzmannii Delille | 1259 | Abutilon grandifolium (Willd.) Sweet | 1359 | Glaucium arabicum Fresen. | 1459 | Avena barbata Pott ex Link |
| 1060 | Psophocarpus tetragonolobus (L.) DC. | 1160 | Erodium touchanyum Delille ex Godr. | 1260 | Abutilon pannosum (G. Forst.) Schtdl. | 1360 | Glaucium corniculatum (L.) Curtis | 1460 | Avena fatua L. |
| 1061 | Retama monosperma (L.) Boiss. | 1161 | Geranium arabicum Forssk. | 1261 | Abutilon theophrasti Medik. | 1361 | Glaucium grandiflorum Boiss. & A. Huet | 1461 | Avena longiglumis Durieu |
| 1062 | Retama raetam (Forssk.) Webb & Berthel. | 1162 | Geranium dissectum L. | 1262 | Alcea acaulis (Cav.) Alef. | 1362 | Hypecoum aegyptiacum (Forssk.) Asch. & Schweinf. | 1462 | Avena sativa L. |
| 1063 | Rhynchosia minima (L.) DC. | 1163 | Geranium macense Boiss. | 1263 | Alcea rosea L. | 1363 | Hypecoum aequilobum Viv. | 1463 | Avena sterilis L. |
| 1064 | Saraca indica L. | 1164 | Geranium molle L. | 1264 | Corchorus depressus (L.) Peterm. | 1364 | Hypecoum imberbe Sm. | 1464 | Brachypodium distachyon (L.) P. Beauv. |
| 1065 | Scorpiurus muricatus L. | 1165 | Geranium rotundifolium L. | 1265 | Corchorus olitorius L. | 1365 | Hypecoum littorale Wulfen | 1465 | Briza maxima L. |
| 1066 | Senegalia laeta (R.Br. ex Benth.) Seigler & Ebinger | 1166 | Monsonia heliostephanoides (Cav.) Boiss. | 1266 | Corchorus tridens L. | 1366 | Hypecoum pendulum L. | 1466 | Briza minor L. |
| 1067 | Senegalia mellifera (Benth.) Seigler & Ebinger | 1167 | Monsonia nivea (Decne.) Webb | 1267 | Corchorus triocularis L. | 1367 | Hypecoum procumbens L. | 1467 | Bromus aegyptiacus Tausch |
| 1068 | Senegalia senegal (L.) Britton | 1168 | Monsonia senegalensis Guill. & Perr. | 1268 | Gossypium barbadense L. | 1368 | Papaver argemone L. | 1468 | Bromus alopecuroides Poir. |
| 1069 | Senna alexandrina Mill. | 1169 | Gisekia pharmacoides L. | 1269 | Gossypium herbaceum L. | 1369 | Papaver decalaisei Hochst. & Steud. ex Elkan | 1469 | Bromus catharticus Vahl |
| 1070 | Senna bicapsularis (L.) Roxb. | 1170 | Myriophyllum spicatum L. | 1270 | Grewia erythraea Schweinf. | 1370 | Papaver decandrum (Forssk.) Medik. | 1470 | Bromus diandrus Roth |
| 1071 | Senna holosericea (Fresen.) Greuter | 1171 | Eloea canadensis Michx. | 1271 | Grewia tenax (Forssk.) Fiori | 1371 | Papaver dubium L. | 1471 | Bromus fasciculatus C. Presl |
| 1072 | Senna italica Mill. | 1172 | Halophila ovalis (R.Br.) Hook.f. | 1272 | Herminia mondia (Ehrenb.) Mast. | 1372 | Papaver humile Fedde | 1472 | Bromus hordeaceus L. |
| 1073 | Senna occidentalis (L.) Link | 1173 | Halophila stipulacea (Forssk.) Asch. | 1273 | Hibiscus diversifolius Jacq. | 1373 | Papaver hybridum L. | 1473 | Bromus inermis Leys. |
| 1074 | Sesbania sericea (Willd.) Link | 1174 | Najas graminea Delille | 1274 | Hibiscus micranthus L.f. | 1374 | Papaver rhoeas L. | 1474 | Bromus japonicus Houtt. |
| 1075 | Sesbania sesban (L.) Merr. | 1175 | Najas horrida A. Braun ex Magnus | 1275 | Hibiscus sabdariffa L. | 1375 | Sesamum alatum Thonn. | 1475 | Bromus lanceolatus Roth |
| 1076 | Styphnolobium japonicum (L.) Schott | 1176 | Najas marina L. | 1276 | Hibiscus tridactylites Lindl. | 1376 | Sesamum indicum L. | 1476 | Bromus lepidus Holmb. |
| 1077 | Sulla coronaria (L.) B.H. Choi & H. Ohashi | 1177 | Najas minor All. | 1277 | Malva aegyptia L. | 1377 | Peplidium maritimum (L.f.) Asch. | 1477 | Bromus madritensis L. |
| 1078 | Sulla spinosissima (L.) B.H. Choi & H. Ohashi | 1178 | Najas pectinata (Pall.) Magnus | 1278 | Malva ludwigii (L.) Soldano, Banfi & Galasso | 1378 | Andrachne aspera Spreng. | 1478 | Bromus pectinatus Thunb. |
| 1079 | Tamarindus indica L. | 1179 | Ottelia alismoides (L.) Pers. | 1279 | Malva multiflora (Cav.) Soldano, Banfi & Galasso | 1379 | Andrachne telephoides L. | 1479 | Bromus pumilio (Trin.) P. M. Sm. |
| 1080 | Taverniera aegyptiaca Boiss. | 1180 | Thalassia hemprichii (Ehrenb. ex Solms) Asch. | 1280 | Malva nicaeensis All. | 1380 | Flueggea virosa (Roxb. ex Willd.) Royle | 1480 | Bromus rigidus Roth |
| 1081 | Tephrosia kassassi Boulos | 1181 | Vallisneria spiralis L. | 1281 | Malva parviflora L. | 1381 | Phyllanthus rotundifolius J.G. Klein ex Willd. | 1481 | Bromus rubens L. |
| 1082 | Tephrosia rubra (Boiss.) Baker | 1182 | Gladiolus italicus Mill. | 1282 | Malvastrum coromandelianum (L.) Garcke | 1382 | Bacopa monnieri (L.) Wettst. | 1482 | Bromus scoparius L. |
| 1083 | Tephrosia purpurea (L.) Pers. | 1183 | Moraea mediterranea Goldblatt | 1283 | Malva sylvestris L. | 1383 | Globularia alypum L. | 1483 | Bromus sterilis L. |
| 1084 | Tephrosia uniflora Pers. | 1184 | Moraea sisyrinchium (L.) Ker Gawl. | 1284 | Melhania denhamii R.Br. | 1384 | Globularia arabica Jaub. & Spach | 1484 | Calamagrostis arenaria (L.) Roth |
| 1085 | Tephrosia villosa (L.) Pers. | 1185 | Juncus acutus L. | 1285 | Melhania philippiae Baker f. | 1385 | Kickxia aegyptiaca (L.) Nabelek | 1485 | Catopodium rigidum (L.) C.E. Hubb. |
| 1086 | Trifolium alexandrinum L. | 1186 | Juncus bufonius L. | 1286 | Pavonia arabica Hochst. & Steud. ex Boiss. | 1386 | Kickxia elatine (L.) Dumort. | 1486 | Cenchrus americanus (L.) Morrone |
| 1087 | Trifolium angustifolium L. | 1187 | Juncus fontanellii J. Gay ex Laharpe | 1287 | Pavonia burchei (DC.) R.A. Dyer | 1387 | Kickxia floribunda (Boiss.) Täckh. & Boulos | 1487 | Cenchrus biflorus Roxb. |
| 1088 | Trifolium argutum Banks & Sol. | 1188 | Juncus hybridus Brot. | 1288 | Pavonia kotschyii Hochst. ex Webb | 1388 | Kickxia spuria (L.) Dumort. | 1488 | Cenchrus ciliaris L. |
| 1089 | Trifolium bullatum Boiss. & Hausskn. | 1189 | Juncus littoralis C.A. Mey. | 1289 | Pavonia senegalensis (Cav.) Leistner | 1389 | Limosella aquatica L. | 1489 | Cenchrus clandestinus (Hochst. ex Chiov.) Morrone |
| 1090 | Trifolium campestre Schreb. | 1190 | Juncus punctatorius L.f. | 1290 | Pavonia triloba Guill. & Perr. | 1390 | Linaria albifrons (Sm.) Spreng. | 1490 | Cenchrus divinus (J.F. Gmel.) Verloove, Govaerts & Buttler |
| 1091 | Trifolium chrysopogon Viv. | 1191 | Juncus rigidus Desf. | 1291 | Sida acuta Burm.f. | 1391 | Linaria chalapensis (L.) Mill. | 1491 | Cenchrus echinatus L. |
| 1092 | Trifolium clusii Godr. | 1192 | Juncus subulatus Forssk. | 1292 | Sida alba L. | 1392 | Linaria haelava (Forssk.) Delille | 1492 | Cenchrus longisetus M.C. Johnston |
| 1093 | Trifolium coeruleum Viv. | 1193 | Ajuga iva (L.) Schreb. | 1293 | Sida ovata Forssk. | 1393 | Linaria micrantha (Cav.) Hoffmanns. & Link | 1493 | Cenchrus orientalis (Rich.) Morrone |
| 1094 | Trifolium dasyneuron C. Presl | 1194 | Clodendrum capitatum (Willd.) Schumacher | 1294 | Sida spinosa L. | 1394 | Linaria tenuis (Viv.) Spreng. | 1494 | Cenchrus pennisetiformis Steud. |
| 1095 | Trifolium elenbergii Sweet | 1195 | Clodendrum formicarium Gürke | 1295 | Marsilea aegyptiaca Willd. | 1395 | Misopates microcarpum (Pomel) D.A. Sutton | 1495 | Cenchrus setaceus (Forssk.) Morrone |
| 1096 | Trifolium fragiferum L. | 1196 | Clodendrum schweinfurthii Gürke | 1296 | Marsilea aethiopica Launert | 1396 | Misopates orontium (L.) Raf. | 1496 | Cenchrus setiger Vahl |
| 1097 | Trifolium incarnatum L. | 1197 | Coleus hadiensis (Forssk.) A.J. Paton | 1297 | Marsilea capensis A. Braun | 1397 | Nanorrhinum acerbianum (Boiss.) Betsche | 1497 | Cenchrus sieberianus (Schtdl.) Verloove |
| 1098 | Trifolium nigrescens Viv. | 1198 | Lamium amplexicaule L. | 1298 | Marsilea minuta L. | 1398 | Nanorrhinum heterophyllum (Schousb.) Ghebr. | 1498 | Cenchrus violaceus (Lam.) Morrone |
| 1099 | Trifolium patens Schreb. | 1199 | Lavandula atriplicifolia Benth. | 1299 | Marsilea strigosa Willd. | 1399 | Plantago afra L. | 1499 | Centropodia forskalii (Vahl) Cope |
| 1100 | Trifolium purpureum Loisel. | 1200 | Lavandula coronopifolia Poir. | 1300 | Cocculus pendulus (J.R. Forst. & G. Forst.) Diels | 1400 | Plantago albicans L. | 1500 | Chloris flagellifera (Nees) P.M. Peterson |

Table (B) Native Species in Egypt according to Royal Botanic Gardens, Kew, online, Source: RBG Kew, 2021 (Cont'd)

| Nu | Name | Nu | Name | Nu | Name | Nu | Name | Nu | Name |
|------|--|------|--|------|---|------|---|------|---|
| 1501 | Chloris gayana Kunth | 1601 | Panicum hygrocharis Steud. | 1701 | Atraphaxis spinosa L. | 1801 | Crucianella aegyptiaca L. | 1901 | Vahlia geminiflora (Caill. & Delile) Bridson |
| 1502 | Chloris pycnosthris Trin. | 1602 | Panicum micaceum L. | 1702 | Calligonum comosum L'Hér. | 1802 | Crucianella maritima L. | 1902 | Lantana viburnoides (Forssk.) Vahl |
| 1503 | Chloris virgata Sw. | 1603 | Panicum repens L. | 1703 | Fallopia convolvulus (L.) Á. Löve | 1803 | Crucianella membranacea Boiss. | 1903 | Lantana × strigocamara R.W. Sanders |
| 1504 | Coelachyrum brevifolium Hochst. & Nees | 1604 | Panicum turgidum Forssk. | 1704 | Persicaria decipiens (R.Br.) K.L. Wilson | 1804 | Cruciata articulata (L.) Ehrend. | 1904 | Phyla nodiflora (L.) Greene |
| 1505 | Coix lacryma-jobi L. | 1605 | Parapholis filiformis (Roth) C.E. Hubb. | 1705 | Persicaria lanigera (R.Br.) Sojak | 1805 | Galium canum Req. ex DC. | 1905 | Priva adhaerens (Forssk.) Chiov. |
| 1506 | Cortaderia selloana (Schult. & Schult.f.) Asch. & Graebn. | 1606 | Parapholis incurva (L.) C.E. Hubb. | 1706 | Persicaria lapathifolia (L.) Delarbre | 1806 | Galium murale (L.) All. | 1906 | Verbena aristigera S.Moore |
| 1507 | Corynephorus divaricatus (Poir.) Breistr. | 1607 | Parapholis marginata Runemark | 1707 | Persicaria limbatia (Meisn.) H.Hara | 1807 | Galium nigricans Boiss. | 1907 | Verbena officinalis L. |
| 1508 | Critipolis delleana (Schult.) Roshev. | 1608 | Paspalum dilatatum Poir. | 1708 | Persicaria maculosa Gray | 1808 | Galium setaceum Lam. | 1908 | Verbena supina L. |
| 1509 | Cutandia dichotoma (Forssk.) Trab. | 1609 | Paspalum distichum L. | 1709 | Persicaria obtusifolia (Täckh. & Boulos) Greuter & Burdet | 1809 | Galium sinaicum (Delile ex Decne.) Boiss. | 1909 | Viola scorpioides Coss. |
| 1510 | Cutandia maritima (L.) Barbey | 1610 | Paspalum racemosum Lam. | 1710 | Persicaria senegalensis (Meisn.) Sojak | 1810 | Galium spurium L. | 1910 | Cyphostemma ternatum (J.F.Gmel.) Desc. |
| 1511 | Cutandia memphitica (Spreng.) Benth. | 1611 | Paspalum vaginatum Sw. | 1711 | Polygonum aviculare L. | 1811 | Galium tricornutum Dandy | 1911 | Zostera noltii Hornem. |
| 1512 | Cymbopogon citratus (DC.) Stapf | 1612 | Phalaris aquatica L. | 1712 | Polygonum bellardii All. | 1812 | Kohautia caespitosa Schnitzl. | 1912 | Balanites aegyptiaca (L.) Delile |
| 1513 | Cymbopogon flexuosus (Nees ex Steud.) W.Watson | 1613 | Phalaris arundinacea L. | 1713 | Polygonum equisetiforme Sm. | 1813 | Oldenlandia capensis L.f. | 1913 | Setetzenia lanata (Willd.) Bullock |
| 1514 | Cymbopogon martini (Roxb.) W.Watson | 1614 | Phalaris canariensis L. | 1714 | Polygonum maritimum L. | 1814 | Oldenlandia corymbosa L. | 1914 | Setetzenia orientalis Decne. |
| 1515 | Cymbopogon nardus (L.) Rendle | 1615 | Phalaris minor Retz. | 1715 | Polygonum melastomac Delile | 1815 | Plocama calycotera (Decne.) M.Backlund & Thulin | 1915 | Tribulus bimucronatus Viv. |
| 1516 | Cymbopogon schoenanthus (L.) Spreng. | 1616 | Phalaris paradoxa L. | 1716 | Polygonum multisetum Delile | 1816 | Rubia tenuifolia d'Urv. | 1916 | Tribulus macropterus Boiss. |
| 1517 | Cynodon dactylon (L.) Pers. | 1617 | Phleum pratense L. | 1717 | Polygonum plebeum R.Br. | 1817 | Theligonum cynocrambe L. | 1917 | Tribulus megistopterus Kralik |
| 1518 | Cynodon transvaalensis Burt Davy | 1618 | Phragmites australis (Cav.) Trin. ex Steud. | 1718 | Rumex aegyptiacus L. | 1818 | Valantia columella (Ehrenb. ex Boiss.) Bald. | 1918 | Tribulus parvispinus C.Presl |
| 1519 | Cynorus coloratus Lehm. ex Steud. | 1619 | Phragmites mauritanus Kunth | 1719 | Rumex cathifolius Campd. | 1819 | Valantia hispida L. | 1919 | Tribulus pentandrus Forssk. |
| 1520 | Cynorus echinatus L. | 1620 | Poa annua L. | 1720 | Rumex crispus L. | 1820 | Rupia cirrhosa (Petagna) Grande | 1920 | Tribulus spuris Kralik |
| 1521 | Dactylis glomerata L. | 1621 | Poa diaphora Trin. | 1721 | Rumex cyprus Murb. | 1821 | Rupia maritima L. | 1921 | Tribulus terrestris L. |
| 1522 | Dactyloctenium aegyptium (L.) Willd. | 1622 | Poa infirma Kunth | 1722 | Rumex dentatus L. | 1822 | Citrus × aurantium L. | 1922 | Zygophyllum aegyptium Hosny |
| 1523 | Dactyloctenium aegyptium (L.) Willd. | 1623 | Poa sinica Steud. | 1723 | Rumex pictus Forssk. | 1823 | Haplophyllum tuberculatum (Forssk.) A.Juss. | 1923 | Zygophyllum album L.f. |
| 1524 | Danthoniopsis barbata (Nees) C.E.Hubb. | 1624 | Polygonum maritimum Willd. | 1724 | Rumex pulcher L. | 1824 | Populus euphratica Olivier | 1924 | Zygophyllum arabicum (L.) Christenh. & Byng |
| 1525 | Desmazeria philistaea (Boiss.) H.Scholz | 1625 | Polygonum monspeliensis (L.) Desf. | 1725 | Rumex simpliciflorus Murb. | 1825 | Salix mucronata Thunb. | 1925 | Zygophyllum arabicum (L.) Christenh. & Byng |
| 1526 | Desmostachya bipinnata (L.) Stapf | 1626 | Polygonum viridis (Gouan) Breistr. | 1726 | Rumex spinosus L. | 1826 | Salix tetrasperma Roxb. | 1926 | Zygophyllum coccineum L. |
| 1527 | Dichanthium annulatum (Forssk.) Stapf | 1627 | Rostraria cristata (L.) Tzelev | 1727 | Rumex vesicarius L. | 1827 | Salix × fragilis L. | 1927 | Zygophyllum creticum (L.) Christenh. & Byng |
| 1528 | Dichanthium foveolatum (Delile) Roberty | 1628 | Rostraria hispida (Savi) Dogan | 1728 | Pontederia crassipes Mart. | 1828 | Salvadora persica L. | 1928 | Zygophyllum decumbens Delile |
| 1529 | Digitaria ciliaris (Retz.) Koeler | 1629 | Rostraria pumila (Retz.) Tzelev | 1729 | Pontederia natans P. Beauv. | 1829 | Thesium humile Vahl | 1929 | Zygophyllum dumosum Boiss. |
| 1530 | Digitaria sanguinalis (L.) Scop. | 1630 | Rostraria rohlfii (Asch.) Holub | 1730 | Portulaca africana (Danin & H.G.Baker) Danin | 1830 | Cardiospermum halicacabum L. | 1930 | Zygophyllum fabago L. |
| 1531 | Digitaria velutina (Forssk.) P. Beauv. | 1631 | Saccharum officinarum L. | 1731 | Portulaca cyprina Danin | 1831 | Mimusops laurifolia (Forssk.) Friis | 1931 | Zygophyllum glutinosum (Delile) Christenh. & Byng |
| 1532 | Digitaria villosa Link | 1632 | Saccharum spontaneum L. | 1732 | Portulaca granulatastellata (Poeell.) Nicot & Jorgoni | 1832 | Anticharis arabica Endl. | 1932 | Zygophyllum indicum (Burm.f.) Christenh. & Byng |
| 1533 | Dinebra retroflexa (Vahl) Panz. | 1633 | Schismus arabicus Nees | 1733 | Portulaca nitida (Danin & H.G.Baker) Nicot & Jorgoni | 1833 | Anticharis glandulosa Asch. | 1933 | Zygophyllum mayanum (Schldt.) Christenh. & Byng |
| 1534 | Diplachne fusca (L.) P. Beauv. ex Roem. & Schult. | 1634 | Schismus barbatus (L.) Thell. | 1734 | Portulaca oleracea L. | 1834 | Anticharis senegalensis (Walp.) Bhandari | 1934 | Zygophyllum molle (Delile) Christenh. & Byng |
| 1535 | Echinochloa colonum (L.) Link | 1635 | Schmidtia pappophoroides Steud. ex J.A. Schmidt | 1735 | Portulaca trituberculata Danin, Domina & Raimondo | 1835 | Jamesbrittenia dissecta (Delile) Kuntze | 1935 | Zygophyllum orientale (C.Presl) Christenh. & Byng |
| 1536 | Echinochloa crus-galli (L.) P. Beauv. | 1636 | Schoenefeldia gracilis Kunth | 1736 | Posidonia oceanica (L.) Delile | 1836 | Scrophularia canina L. | 1936 | Zygophyllum paulayanum (J. Wagner & Vrieh.) Christenh. & Byng |
| 1537 | Echinochloa pyramidalis (Lam.) Hitchc. & Chase | 1637 | Setaria geminata (Forssk.) Veldkamp | 1737 | Potamogeton crispus L. | 1837 | Scrophularia deserti Delile | 1937 | Zygophyllum propinquum Decne. |
| 1538 | Echinochloa stagnina (Retz.) P. Beauv. | 1638 | Setaria italica (L.) P. Beauv. | 1738 | Potamogeton lucens L. | 1838 | Scrophularia syriaca Benth. | 1938 | Zygophyllum scabrum (Forssk.) Christenh. & Byng |
| 1539 | Ehrharta calycina Sm. | 1639 | Setaria megaphylla (Steud.) T.Durand & Schinz | 1739 | Potamogeton nodosus Poir. | 1839 | Scrophularia xanthoglossa Boiss. | 1939 | Zygophyllum simplex L. |
| 1540 | Eleusine africana Kenn.-O'Byrne | 1640 | Setaria obtusifolia (Delile) Morrone | 1740 | Setaria perfoliata L. | 1840 | Verbascum letoumeuxii Asch. | | |
| 1541 | Eleusine coracana (L.) Gaertn. | 1641 | Setaria pumila (Poir.) Roem. & Schult. | 1741 | Potamogeton pusillus L. | 1841 | Verbascum sinuatum L. | | |
| 1542 | Eleusine floccifolia Spreng. | 1642 | Setaria verticillata (L.) P. Beauv. | 1742 | Potamogeton schweinfurthii A. Benn. | 1842 | Cestrum × cultum Francey | | |
| 1543 | Eleusine indica (L.) Gaertn. | 1643 | Setaria viridis (L.) P. Beauv. | 1743 | Potamogeton trichoides Cham. & Schtdl. | 1843 | Datura innoxia Mill. | | |
| 1544 | Elionurus royleanus Nees ex A.Rich. | 1644 | Sorghum arundinaceum (Desv.) Stapf | 1744 | Stuckenia pectinata (L.) Börner | 1844 | Datura metel L. | | |
| 1545 | Enneapogon desvauxii P. Beauv. | 1645 | Sorghum bicolor (L.) Moench | 1745 | Zannichellia palustris L. | 1845 | Datura stramonium L. | | |
| 1546 | Enneapogon lophotrichus Chiov. ex H.Scholz & P.König | 1646 | Sorghum halepense (L.) Pers. | 1746 | Coris monspeliensis L. | 1846 | Hyoscyamus albus L. | | |
| 1547 | Enneapogon persicus Boiss. | 1647 | Sorghum virgatum (Hack.) Stapf | 1747 | Lysimachia arvensis (L.) U.Manns & Anderb. | 1847 | Hyoscyamus aureus L. | | |
| 1548 | Entropogon pterius (Kunth) Clayton | 1648 | Sorghum × drummondii (Nees ex Steud.) Millsp. & Chase | 1748 | Lysimachia linum-stellatum L. | 1848 | Hyoscyamus boveanus (Dunal) Asch. & Schweinf. | | |
| 1549 | Eragrostis aegyptiaca (Willd.) Delile | 1649 | Sphenopus divaricatus (Gouan) Rchb. | 1749 | Lysimachia ovalis (Ruiz & Pav.) U.Manns & Anderb. | 1849 | Hyoscyamus desertorum (Asch. ex Boiss.) Tackh. | | |
| 1550 | Eragrostis aspera (Jacq.) Nees | 1650 | Sporobolus aculeatus (L.) P.M.Peterson | 1750 | Primula verticillata Forssk. | 1850 | Hyoscyamus muticus L. | | |
| 1551 | Eragrostis barrelieri Daveau | 1651 | Sporobolus alopecuroides (Miller & Mitterp.) P.M.Peterson | 1751 | Samolus valerandi L. | 1851 | Lycium europaeum L. | | |
| 1552 | Eragrostis cilianensis (All.) Vignolo ex Janch. | 1652 | Sporobolus natalensis (Steud.) T.Durand & Schinz | 1752 | Actinopteryx semiflabellata Pic.Serm. | 1852 | Lycium schweinfurthii Dammer | | |
| 1553 | Eragrostis ciliaris (L.) R.Br. | 1653 | Sporobolus niliacus (Fig. & De Not.) P.M.Peterson | 1753 | Adiantum capillus-veneris L. | 1853 | Lycium shawii Roem. & Schult. | | |
| 1554 | Eragrostis japonica (Thunb.) Trin. | 1654 | Sporobolus pungens (Schreb.) Kunth | 1754 | Anogramma leptophylla (L.) Link | 1854 | Nicandra physalodes (L.) Gaertn. | | |
| 1555 | Eragrostis minor Host | 1655 | Sporobolus schoenoides (L.) P.M.Peterson | 1755 | Cosentinia vellea (Aiton) Tod. | 1855 | Nicotiana glauca Graham | | |
| 1556 | Eragrostis multiflora Trin. | 1656 | Sporobolus spicatus (Vahl) Kunth | 1756 | Onychium divaricatum (Poir.) Alston | 1856 | Nicotiana plumbaginifolia Viv. | | |
| 1557 | Eragrostis nitida Link | 1657 | Sporobolus wrightii Scribn. | 1757 | Adonis dentata Delile | 1857 | Nicotiana rustica L. | | |
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| 1559 | Eragrostis sarmentosa (Thunb.) Trin. | 1659 | Stipagrostis acutiflora (Trin. & Rupr.) De Winter | 1759 | Anemone coronaria L. | 1859 | Physalis angulata L. | | |
| 1560 | Eragrostis tef (Zuccagn) Trotter | 1660 | Stipagrostis ciliata (Desf.) De Winter | 1760 | Delphinium flavum DC. | 1860 | Physalis ixocarpa Brot. ex Hornem. | | |
| 1561 | Eragrostis tenuifolia (A.Rich.) Hochst. ex Steud. | 1661 | Stipagrostis hirtiglauca (Steud. ex Trin. & Rupr.) De Winter | 1761 | Delphinium nanum DC. | 1861 | Solanum aethiopicum L. | | |
| 1562 | Eragrostis tremula Hochst. ex Steud. | 1662 | Stipagrostis lanata (Forssk.) De Winter | 1762 | Nigella arvensis L. | 1862 | Solanum coagulans Forssk. | | |
| 1563 | Festuca brevis (Boiss. & Kotschy) Asch., Schweinf. & Muschl. | 1663 | Stipagrostis obtusa (Delile) Nees | 1763 | Nigella sativa L. | 1863 | Solanum elaeagnifolium Cav. | | |
| 1564 | Festuca bromoides L. | 1664 | Stipagrostis paradisea (Edgew.) De Winter | 1764 | Ranunculus arvensis L. | 1864 | Solanum forskalii Dunal | | |
| 1565 | Festuca fasciculata Forssk. | 1665 | Stipagrostis plumosa (L.) Munro ex T.Anderson | 1765 | Ranunculus asiaticus L. | 1865 | Solanum incanum L. | | |
| 1566 | Festuca myuros L. | 1666 | Stipagrostis raddiana (Savi) De Winter | 1766 | Ranunculus bulbosus L. | 1866 | Solanum laxum Spreng. | | |
| 1567 | Festuca pectinella Delile | 1667 | Stipagrostis scoparia (Trin. & Rupr.) De Winter | 1767 | Ranunculus cornutus DC. | 1867 | Solanum linnaeanum Hepper & P.-M.L.Jaeger | | |
| 1568 | Gastridium phaeoides (Nees & Meyen) C.E.Hubb. | 1668 | Stipagrostis shawii (H.Scholz) H.Scholz | 1768 | Ranunculus millefolius Banks & Sol. | 1868 | Solanum macrocarpon L. | | |
| 1569 | Halopyrum mucronatum (L.) Stapf | 1669 | Stipagrostis unilumis (Licht.) De Winter | 1769 | Ranunculus muricatus L. | 1869 | Solanum memphiticum J.F.Gmel. | | |
| 1570 | Hemarthra altissima (Poir.) Stapf & C.E.Hubb. | 1670 | Stipagrostis vulnerans (Trin. & Rupr.) De Winter | 1770 | Ranunculus rionii Lager | 1870 | Solanum nigrum L. | | |
| 1571 | Holcus annuus Salz. ex C.A.Mey. | 1671 | Stipa lagascae Roem. & Schult. | 1771 | Ranunculus saniculifolius Viv. | 1871 | Solanum pseudocapsicum L. | | |
| 1572 | Hordeum marinum Huds. | 1672 | Stipa letoumeuxii Trab. | 1772 | Ranunculus scleratus L. | 1872 | Solanum scabrum Mill. | | |
| 1573 | Hordeum murinum L. | 1673 | Stipellula capensis (Thunb.) Röser & Hamasha | 1773 | Ranunculus sphaerospermus Boiss. & C.I.Blanche | 1873 | Solanum schimperianum Hochst. | | |
| 1574 | Hordeum spontaneum K.Koch | 1674 | Tetragonum villosus Desf. | 1774 | Ranunculus trichophyllus Chaix | 1874 | Solanum seaforthianum Andrews | | |
| 1575 | Hordeum vulgare L. | 1675 | Themeda triandra Forssk. | 1775 | Cayusea hexagona (Forssk.) M.L.Green | 1875 | Solanum villosum Mill. | | |
| 1576 | Hypparrhenia hirta (L.) Stapf | 1676 | Thinopyrum elongatum (Host) D.R.Dewey | 1776 | Ochradenus baccatus Delile | 1876 | Solanum virginianum L. | | |
| 1577 | Imperata cylindrica (L.) P. Beauv. | 1677 | Thinopyrum junceum (L.) Á. Löve | 1777 | Oligomeris linifolia (Vahl ex Hornem.) J.F. Macbr. | 1877 | Solanum wendlandii Hook. f. | | |
| 1578 | Lagurus ovatus L. | 1678 | Tragus berteronianus Schult. | 1778 | Randonia africana Coss. | 1878 | Withania somnifera (L.) Dunal | | |
| 1579 | Lamarckia aurea (L.) Moench | 1679 | Tragus racemosus (L.) All. | 1779 | Reseda alba L. | 1879 | Sphenoclea zeylanica Gaertn. | | |
| 1580 | Lasiurus scindicus Henrad | 1680 | Tricholaena teneriffae (L.f.) Link | 1780 | Reseda arabica Boiss. | 1880 | Reaumuria alternifolia (Labill.) Britten | | |
| 1581 | Leersia hexandra Sw. | 1681 | Trichoneura mollis (Kunth) Ekman | 1781 | Reseda decursiva Forssk. | 1881 | Reaumuria hirtella Jaub. & Spach | | |
| 1582 | Leptochloa panicea (Retz.) Ohwi | 1682 | Triplachne nitens (Guss.) Link | 1782 | Reseda lutea L. | 1882 | Reaumuria vermiculata L. | | |
| 1583 | Leptothrium senegalense (Kunth) Clayton | 1683 | Triphaps pumilio R.Br. | 1783 | Reseda luteola L. | 1883 | Tamarix amplexicaulis Ehrenb. | | |
| 1584 | Lolium arundinaceum (Schreb.) Darbysh. | 1684 | Trisetaria gumacea (Boiss.) Maire | 1784 | Reseda muricata C.Presl | 1884 | Tamarix aphylla (L.) H.Karst. | | |
| 1585 | Lolium mediterraneum (Hack.) Benth. & Galles, Poggi, Scazzetti & Sestini | 1685 | Trisetaria linearis Forssk. | 1785 | Reseda odorata L. | 1885 | Tamarix arborea (Sieber ex Ehrenb.) Bunge | | |
| 1586 | Lolium multiflorum Lam. | 1686 | Trisetaria macrochaeta (Boiss.) Maire | 1786 | Reseda orientalis (Müll.Arg.) Boiss. | 1886 | Tamarix macrocarpa (Ehrenb.) Bunge | | |
| 1587 | Lolium perenne L. | 1687 | Triticum aestivum L. | 1787 | Reseda phytoloma L. | 1887 | Tamarix nilotica (Ehrenb.) Bunge | | |
| 1588 | Lolium rigidum Gaudin | 1688 | Triticum turgidum L. | 1788 | Reseda pruinosa Delile | 1888 | Tamarix passerinoides Delile ex Decne. | | |
| 1589 | Lolium temulentum L. | 1689 | Urochloa deflexa (Schumacher) H.Scholz | 1789 | Reseda umigera Webb | 1889 | Tamarix tetragyna Ehrenb. | | |
| 1590 | Lygum spartum Loeff. ex L. | 1690 | Urochloa leersoides (Hochst.) A.M.Torres & C.M.Morton | 1790 | Rhamnus disperma Ehrenb. ex Boiss. | 1890 | Thymelaea hirsuta (L.) Endl. | | |
| 1591 | Megathyrus maximus (Jacq.) B.K.Simon & S.W.L.Jacobs | 1691 | Urochloa mutica (Forssk.) T.Q.Nguyen | 1791 | Rhamnus oleoides L. | 1891 | Typha domingensis Pers. | | |
| 1592 | Melanocorypha abyssinica (R.Br. ex Fresen.) Hochst. | 1692 | Urochloa panicoides P. Beauv. | 1792 | Sageretia thea (Osbeck) M.C.Johnst. | 1892 | Typha elephantina Roxb. | | |
| 1593 | Melinis minutiflora P. Beauv. | 1693 | Urochloa ramosa (L.) T.Q.Nguyen | 1793 | Ziziphus lotus (L.) Lam. | 1893 | Forsskaolea tenacissima L. | | |
| 1594 | Miscanthus sinensis Andersson | 1694 | Urochloa repta (L.) Stapf | 1794 | Ziziphus spina-christi (L.) Desf. | 1894 | Forsskaolea viridis Ehrenb. ex Webb | | |
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Table (C) Native Subspecies in Egypt according to Royal Botanic Gardens, Kew, Online, Source: RBG Kew, 2021

Table D: Native Species in Egypt: Variety and Forms

Table (D) Native Variety and Forms in Egypt according to Royal Botanic Gardens, Kew, Online, Source: RBG Kew, 2021

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