Hochschule Anhalt
Anhalt University of Applied Sciences

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

Aya Mohamed Farid ElMeligy
MLA- 4069696

Masters' student, MLA, Anhalt Hochschule, Bernburg, Germany
Teaching Assistant, Architectural Department
Faculty of Engineering- MUST University- Egypt

Thesis submitted in partial fulfillment of the requirements for the degree of

Master of Landscape Architecture
Anhalt Hochschule, Bernburg, Germany

Department of Agriculture, Home Economics and Nutrition, Landscape Architecture and Nature Conservancy

April 2022
Bernburg, Germany

First Examiner: Prof. Dr. Alexander Kader
Second Examiner: Prof. Dr. Ahmed Haron

Planting Consultant: Prof. Dr. Wolfram Kircher

Master of Landscape Architecture Program (MLA)

(ElMeligy, Aya)

(Thesis "Environmental Impact of Constructed Wetland Parks towards achieving Sustainability Case Study Wetland Park, 10th Ramadan City", 218 pages, 183 figures, 67 Tables, 2022)

Keywords:

Constructed Wetland Parks, Sustainable Landscape, Environmental Impact Assessment, Multifunctional Parks, Climate Change, Water Scarcity, Wastewater Reuse, Water Management, Sustainability, Catalyst project, Urban Development

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, CWPs, 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.

ACKNOWLEDGEMENTS

I would like to thank my thesis advisors at Anhalt University, Germany, **Prof. Dr. Alexander Kader**; for your endless support, understanding and generosity of spirit. I would like to further extend my gratitude for your appreciated valuable time, Knowledge and guidance as well as your kind co-operation and encouragement, guidance, invaluably constructive criticism and friendly advice.

I would also like to thank my thesis advisors **Prof. Dr. Ahmed Haron**; my deepest gratitude, for being abundantly helpful since my undergraduate study years and for always offering invaluable assistance, support and guidance. Such guidance, encouragement, suggestions and constructive criticism have contributed immensely to the evolution of my ideas and knowledge, helping me finally steer to the topic.

My sincere appreciation to **Prof. Dr. Wolfram Kircher**, my planting design professor at Anhalt university, Bernburg, Germany, for your supportive consultancy during the preparation of the plants section and for your appreciated valuable time and useful critiques.

I want to express my love and gratitude to my Parents. My *Dad*, **Prof. Dr. Mohamed Fraid ElMiligi** and my precious *Mum*, **Amal ELRagy;** my ultimate role models, for always believing in me and for your unconditional encouragement, whose love and guidance kept me on track in whatever I pursue. To **my beloved family** for their prayers and support throughout my study years and for their endless love.

I am profoundly grateful to A.L. **Rasha Mahmoud Gaber**, my role model, best friend and instructor; my sincerest gratitude for the useful comments, remarks and engagement; for introducing me to the topic as well as for the support along the way. You have kindly and willingly given me your precious time as well as your knowledge that helped me put all the pieces together. I will be grateful forever for your love. This research project would not have been possible without your ultimate support.

My gratitude to Misr University for Science and Technology, Egypt, **MUST**, and my profound gratitude to **Prof. Dr. Baher Aboustait**, the former dean of Faculty of Engineering, for your sincere support, valuable guidance and encouragement to pursue my master's study in Germany, I will eternally be thankful for you backing me up.

My sincere gratitude for all my beloved friends and colleagues in the Academic Research Group of the Wetland Park Project, 10th of Ramadan, Egypt and for everyone who have supported me throughout my entire study years. Thank you for everything I learned from every one of you, for the friendship and for the moments and laughter.

I am grateful for the support received from the **Academic Research Group** of the 10th of Ramadan Wetland Park project. The Landscape Architecture Design Team: **Arch Space Group**; the Project Host: **CHI**, Cairo Higher Institute for Engineering Computer Science and Management; Project Partners: **NWRC**, National Water Research Center in Egypt and **NUCA**, New Urban Communities Authority; and the funding organization **STDF**, Science and Technology Development Fund Egypt. I am grateful for the sharing of the information and primary data for the project and the simulation of water performance reports and project's plans and sections to continue my analysis for the estimated project's performance analysis.

My heartfelt love and appreciation go out to everyone who will benefit from this work, as well as to everyone who cares enough about nature and the environment to take action, in order to make the world a better place to live, for humans and biodiversity. For everyone who contributes to the improvement of sustainability and quality of life, Thank you.

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 El Meligy

Date: 01.04.2022

TABLE OF CONTENTS

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

Environmental	Sociocultural	Economic
Water quality Improvement	Social Interaction	Water treatment cost reduction
Flooding Control	Enhance Aesthetics	Boost Property Values
Biodiversity Enhancement	Nature Appreciation	Materials Reuse
Air Quality Improvement	Better Healthful lifestyle	Generate employment possibilities
Atmospheric CO_2 Reduction	Offering Public recreation	Food Production
Energy Production	Offering Educational options	Tourist Attractions
Eleminate Urban Heat Island		
Noise Pollution Reduction		

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 though 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.

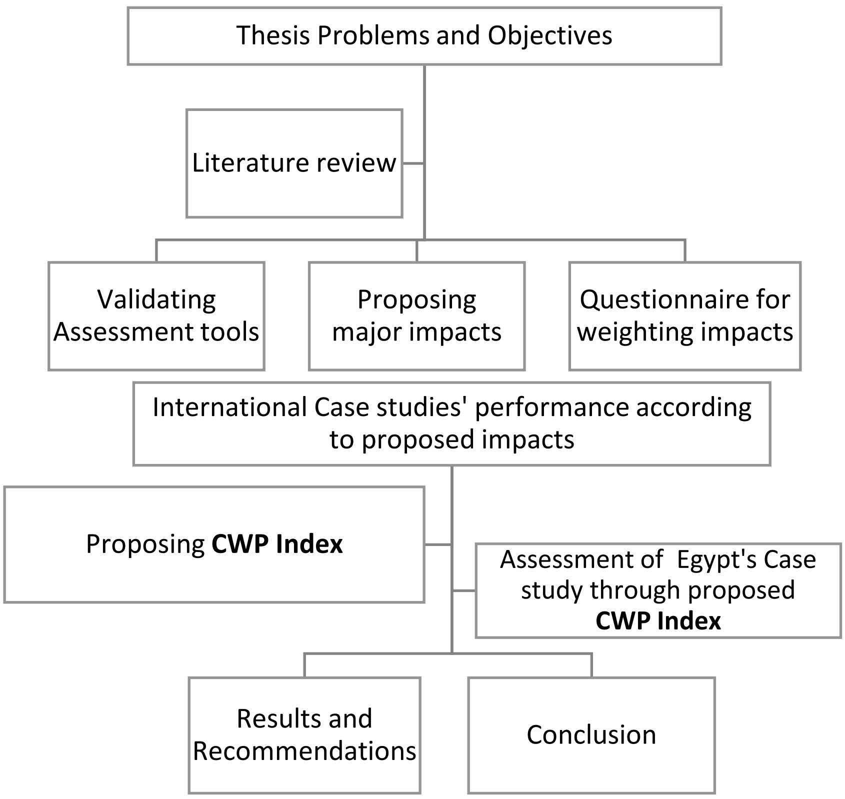


Fig. (2) Thesis Approach, *Source: Author*

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**	•Research Background and Methodology
Chapter 2 **CWP Approaches & Benefits**	Literature Review •Definitions of Wetlands / Constructed wetland / CW parks • Benefits and role of wetland parks for ecology / Biodiversity • Environmenta Impact Assessment, EIA
Chapter 3 **Environmental Assessment Indicators for CWP**	• Environmental; *Climatic, Sustainability, Biodiversity, Water* • Social and cultural; *Community, Social, Aesthetic* • Economy and Technology; *Economic, Technical values*
Chapter 4 **CWP International Case Studies comparative analysis**	Comparative Study • Case studies of top constructed wetland parks approaches • Criteria: Park, Arid, 10 years, Scale • *Riyad, Tangshan, Tianjin, Shanghai, Los Angeles* • Comparative analysis and achievement based on Indicators
Chapter 5 **Assessment Tool**	•CWP Assessment Index Framework • *Proposing CWP Index for Assessment*
Chapter 6 **Case Study, Egypt**	• "Case study: Wetland Park Egypt" • Park's performance analysis and its influence on sustainability • Park's Impace assessment accordig to proposed CWP Index
Chapter 7 **Conclusion**	• 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.

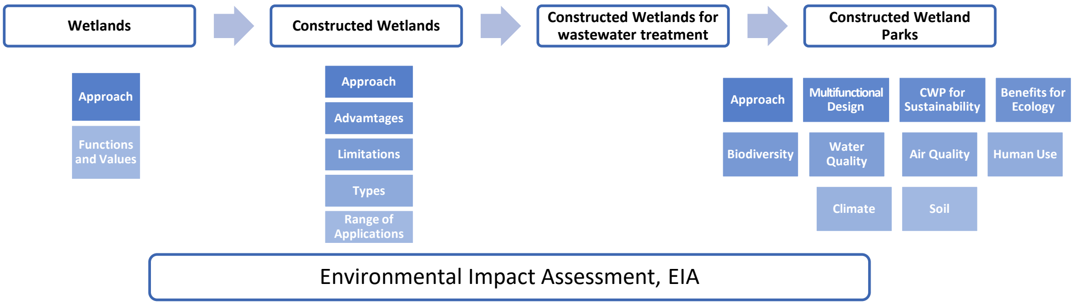


Fig. (4) Chapter 2, Methodology and structure, Source: Author

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)

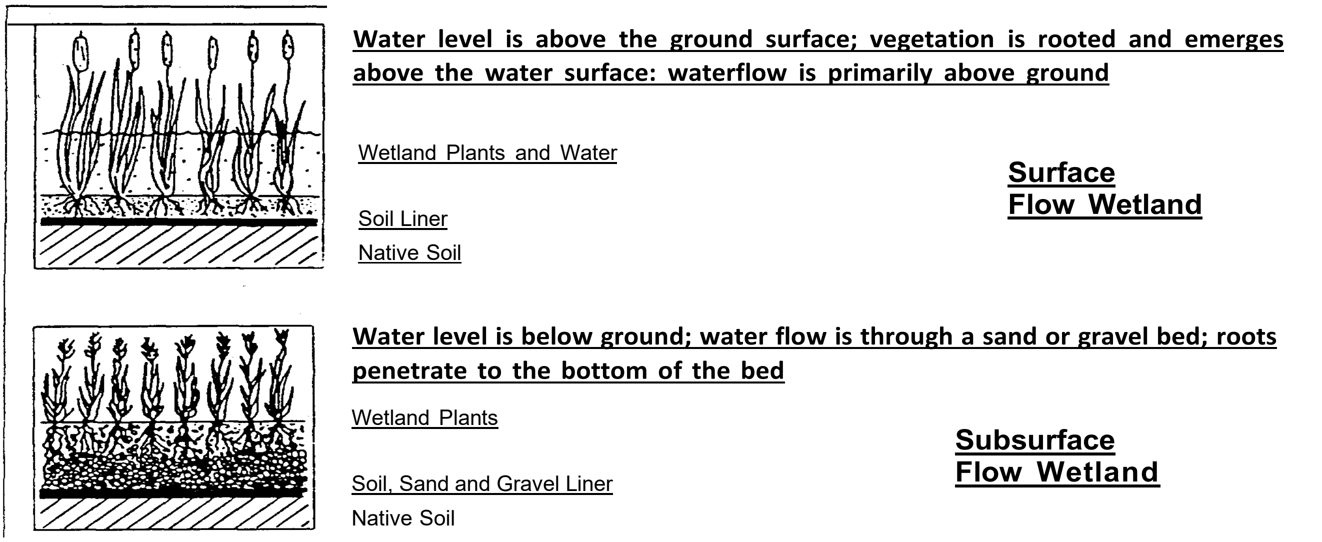


Fig. (5) Surface and subsurface flow constructed wetlands (from Water Pollution Control Federation 1990).
Source: (Davis, L., 1995)

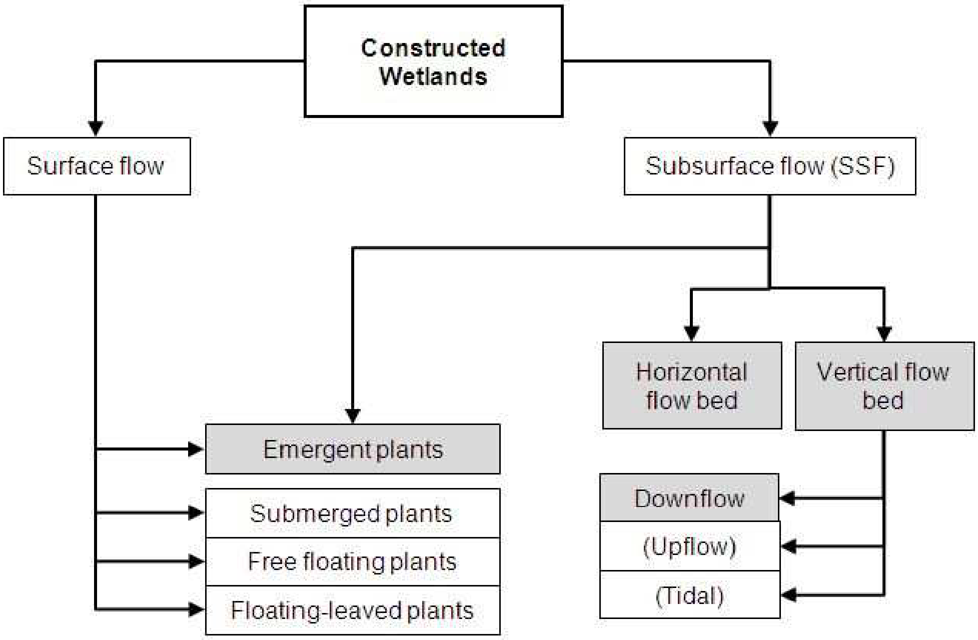


Fig. (6) Constructed wetlands Classification (modified from Vymazal and Kroepfelová, 2008).
"Emergent plants" are a type of macrophyte where the leaves are above the water level.
"Macrophyte" are aquatic plants that normally grow in or near water
Source: (Hoffmann, H., 2011)

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 BOD_5, 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, CWPs:

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)

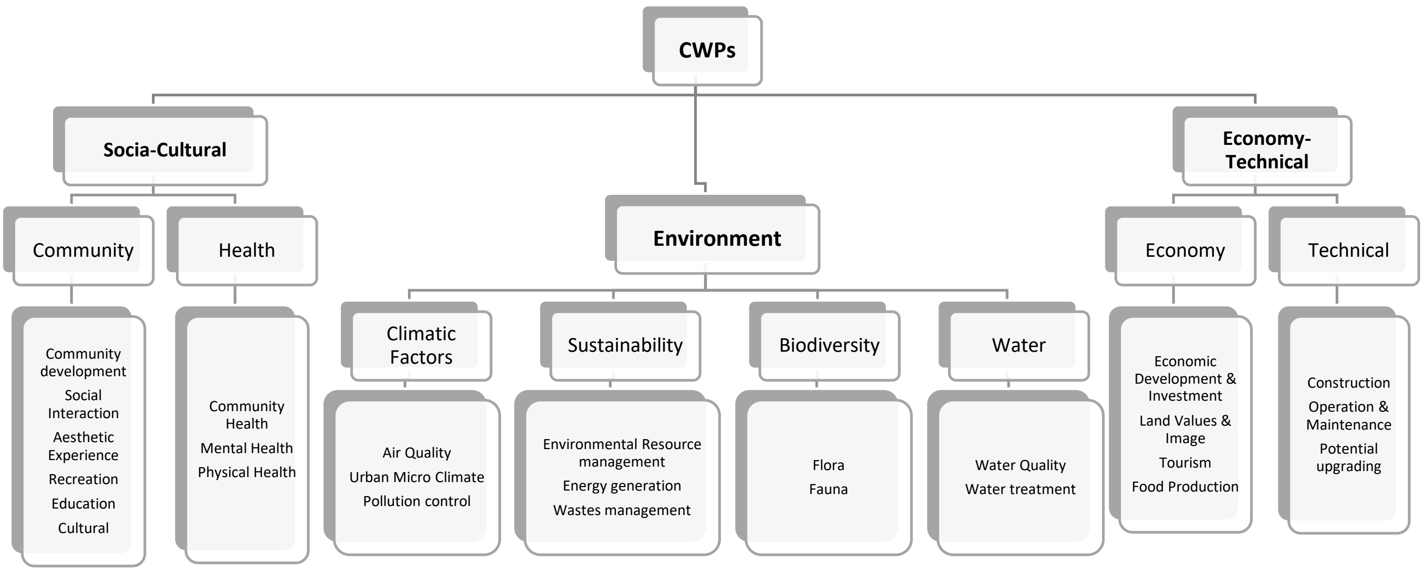
- Improvement of the water quality through the absorption and removal of sediments, nutrients and other pollutants
- Water storage and flood protection
- Groundwater recharge
- Support in the initial production and in the design of food webs,
  - Photosynthesis,
  - Wildlife
  - Food web and habitat 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 CO_2 Seizure, Modification of air components:

Trees sequester atmospheric CO_2 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 CO_2 from the atmosphere (Wee, M., 1999). Calculations by (Akbari, H., 2002) showed an average CO_2 removal of about 4.6 kg per year over the life of a tree up to a crown width of 50 m^2. As the tree grows, the rate of carbon sequestration increases to 11 kg per year (more than 50 m^2 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 CO_2 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 CO_2 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)

CO_2 (kg/year/plant) = total dry weight × 0.5 × 3.667 **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 allelometric 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)

(**T**) trunk $\log10(y) = 2.32\log10(x) - 0.95$

(**B**) branches $\log10(y) = 2.35\log10(x) - 1.84$

(**R**) roots $\log10(y) = 1.98\log10(x) - 1.10$

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

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

DBH *Circumference / 3.14 (π)*

(**TDW**) **Total dry weight / plant = T + B + R** **Equation (B)**

CO_2 sequestered /year /plant (in Kg) = **TDW / age of plant** **Equation (C)**

CO_2 seq. /year /plant species = CO_2 seq. per plant X No. of plants **Equation (D)**

Total Park's CO_2 seq. /year = Sum of CO_2 seq./year/plants for all species **Equation (E)**

To estimate the probable value of CO_2 sequestration the next steps could be used: (Di-Cara, F., et al., 2020)

In the case of **urban trees**, indicative average values of CO_2 absorption range between 12.46 - 21.60 kg CO_2/year/plant (Municipality of Carimate, 2017; Zirkle et al. 2012), with an average of (17.03 kg CO_2/year/plant).

Theoretical Park's CO_2 seq. /year = 17.03 X No. of plants in Park **Equation (F)**

Average Park's CO_2 seq. /year = $$\frac{\textbf{Equation E + Equation F}}{\textbf{2}}$$ **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,

Theoretical shrub CO_2 seq. /year = 0.56 X No. of shrubs in Park **Equation (H)**

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

Unit reference Value = $$\frac{\textbf{CO2 seizure value}}{\textbf{Park's surface area.}}$$ **Equation (I)**

To estimate the amount of oxygen released by the plants, the photosynthesis formula shows that for each mole of CO_2 absorbed, a mole of O_2 is emitted. The quantity of O_2 emitted into the atmosphere, could be obtained from the calculated kg of CO_2 using the molar masses (Nowak, D., et al. 2007; Di-Cara, F., et al., 2020)

$$O_2\ (kg/year) = CO_2\ sequestered\ (kg/year) \times (MMO_2/MMCO_2) \qquad \text{Equation (J)}$$

Where $MM\ O_2 = 31.998$ g/mol

$MM\ CO_2 = 44.009$ 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:

$$\text{No. of people supplied by } O_2 = \text{Park's annual emitted } O_2 / 0.80 \qquad \text{Equation (K)}$$

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:

$$\text{No. of trees required/ area m2} = \frac{\text{Total CO2 emissions}}{\text{average annual CO2 seized / tree}} \qquad \text{Equation (L)}$$

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 PM_{10}, 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 (PM_{10}, O_3, NO_2, SO_2, CO) absorbed or retained by Park's vegetation:

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

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

n number of plants present for each diameter category

Total Pollutant absorbed by species (kg/year) = sum of all diameter category **Equation (N)**

Total Pollutant absorbed by Park (kg/year) = sum of all species **Equation (O)**

2.5.3.2. Compensation for Pollutants Emitted into the Atmosphere

Similar to the compensation of CO_2, the number of trees needed to absorb or suppress various released pollutants in the atmosphere by various human activities is estimated as follows:

$$\textbf{No. of trees required/ area m2} = \frac{\textbf{Total Pollutant emissions}}{\textbf{average annual seized / tree}} \quad \textbf{Equation (P)}$$

A healthy, full-grown tree absorbs on average about 0.42 kg of pollutants per year (considering only O_3, NO_2, SO_2 ePM_{10}). (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 CO_2 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 colurna, 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 calleriana.. (Di-Cara, F., et al., 2020)

2.5.3.3. Measurement of NO_2 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 NO_2. 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 NO_2 concentration decreases, if passes through the plants, which indicates that the nitrogen dioxide gas has been absorbed by the plant. The absorption rate of NO_2. was estimated by the equation: (Taha, T., 2009)

$$Q_{Cin} - Q_{cout} - Vr = O$$

where Q_{Cin} → No_2 concentration in **μg/m³**
In the event of gas entering the plant basin.

Q_{cout} → No_2 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 NO_2 gas concentration, with a ratio between Q_{Cin} and Q_{cout} ranged between 26% and 40% and NO_2 uptake ranged between 0.3 to 0.73 $Mg/m^3.s$, increasing with the increase of amount of No_2 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 m^2 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)

$$\text{Specific Heat } Q(\text{kcal}) = [m(\text{kg}) * c\,(\text{kcal/kg °C}) * \Delta T(\text{°C})] \qquad \text{Equation (Q)}$$

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

For better understanding, Calculating the volume of air occupied by an apartment of 100 m^2 (on average 300 m^3), considering the volume of air within the canopy of the plants in a hypothetical nursery of 0.29 km^2 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 m^2; or to that of 1020 nurseries of 0.29 km^2. 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 m^2 or 204 nurseries of 29 km^2. (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 (policoltures) 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 m^2. (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 O_3 levels in the city

2. **CO_2 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, deadly 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 albostriatus and Cyperus alternifolius (Umbrella sedge)
- Cyperus haspens (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; Mureșan, 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, theses mechanisms include: (Davis, L., 1995; Mureșan, 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 O_3 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, coil, 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 <u>type of vegetation</u>; 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 ≥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 ≤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	*Planting - Pruning (Removal of leaves / branches / fruits), Irrigation, Repair of artifacts, Legal and administrative fees.... etc.*

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 CO_2 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)

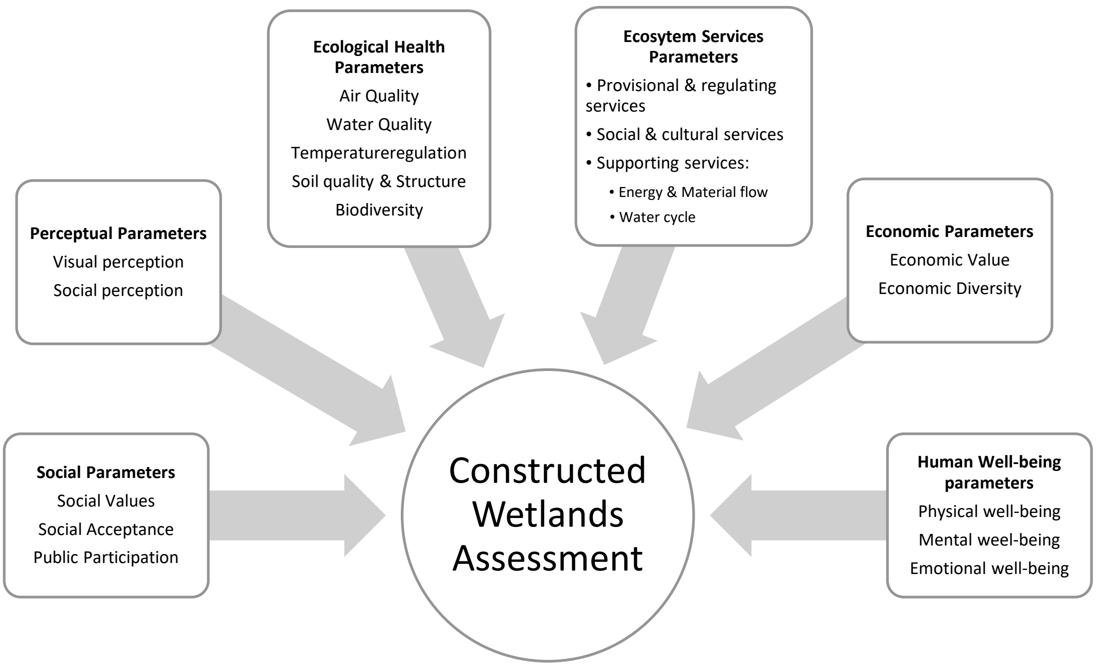


Fig. (8) Conceptual Framework for multifunction constructed wetlands assessment, *Source: Garber, R., 2020*

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.

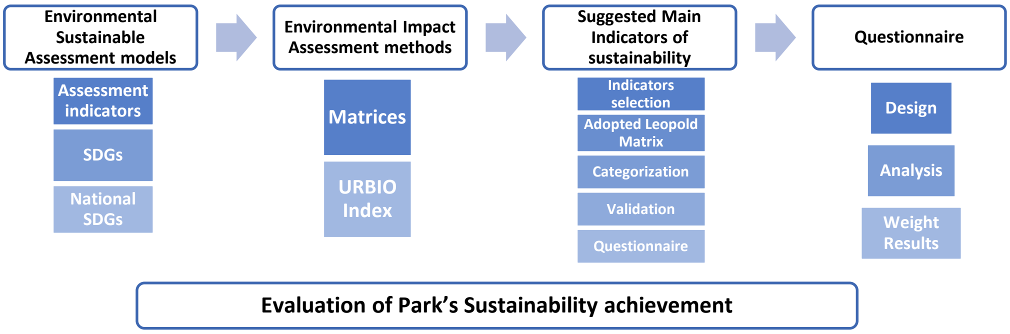


Fig. (9) Chapter 3, Methodology and structure, Source: Author

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. (Çiftçioğlu, 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*

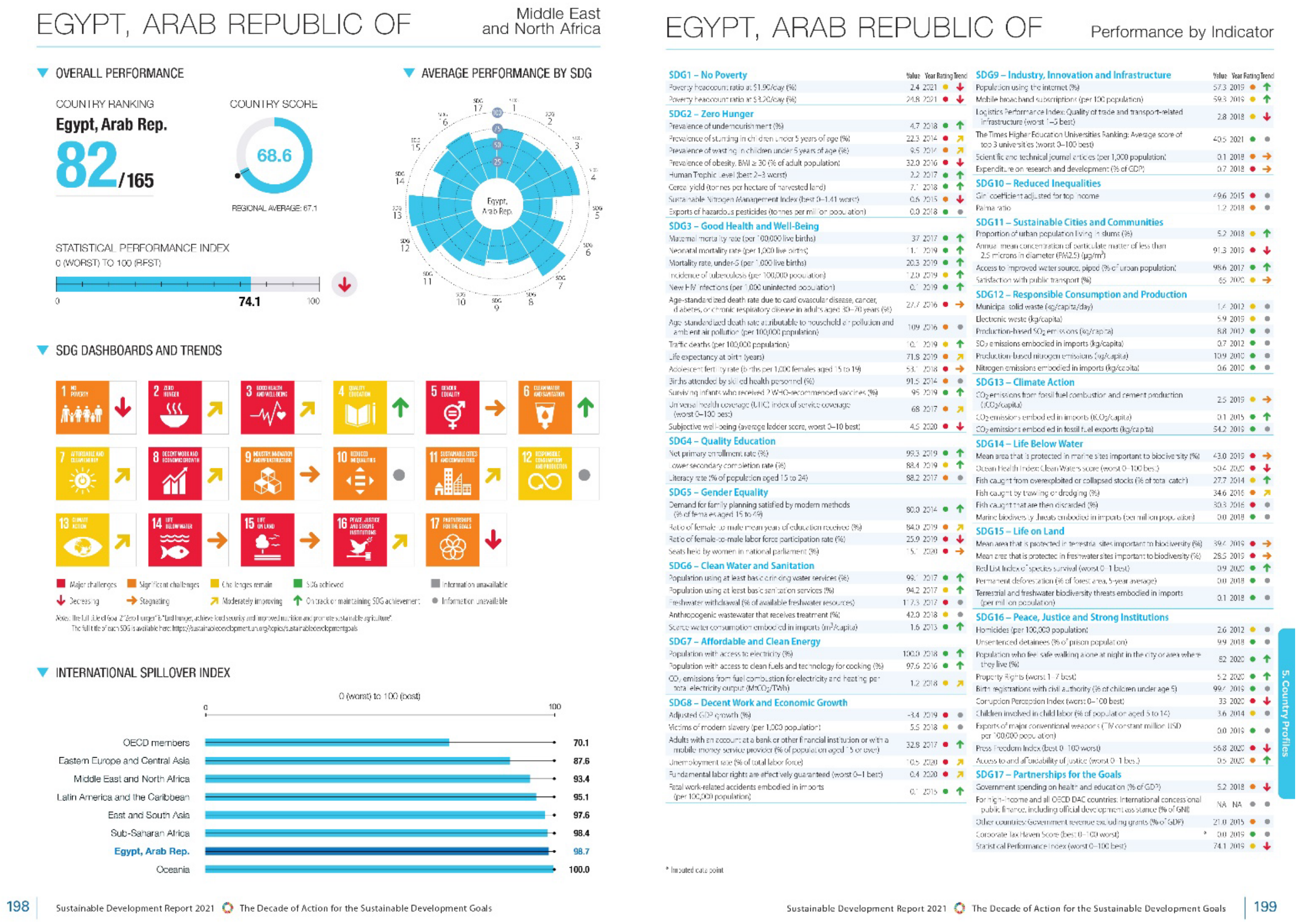


Fig. (11) Egypt's Decade of Action for the Sustainable Development Goals, *Source: Sustainable Development Report 2021*

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)(μg/m³)

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) (μg/m³)	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)

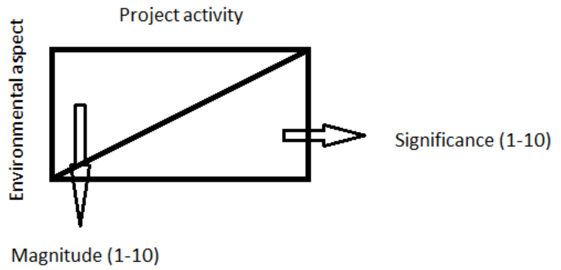


Fig. (13) Leopold matrix Cell, Source: Babu, S., 2016

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 metrices 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)

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

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

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).

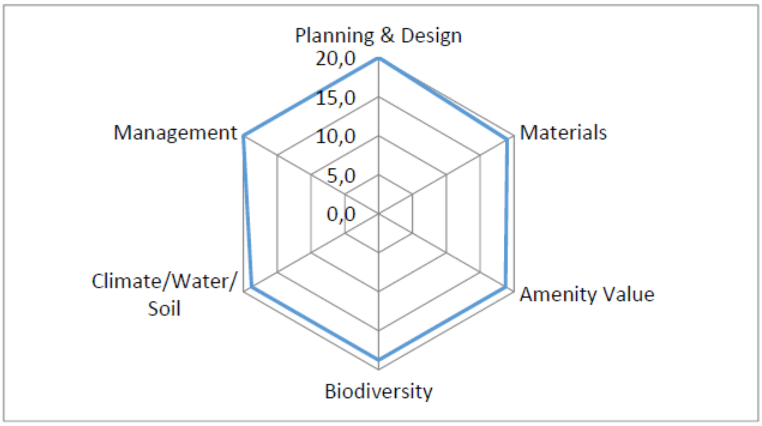


Fig. (14) URBIO Index outcome,
Source: Müller, N. et al. 2016

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 be 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) **S*ocial 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
	2. Fauna	a. Birds
		b. Land animals, including reptiles
		d. Benthic organisms
		e. Insects
		f. Microfauna
		h. Barriers
		i. Corridors
C. Cultural factors	1. Land use	a. Wilderness and opne spaces
		b. Wetlands
	2. Recreation	f. Picnicking
	3. Aesthetics and human interest	a. Scenic view and vistas
		b. Wilderness qualities
		c. Open space qualities
		d. Landscape design
		e. Unique physical features
		f. Parks and reserves
	4. Cultural status	a. Cultural patterns (life style)
		b. Health and safety
		c. Employment
		d. Population density
	5. Man-made facilities and activities	a. Structures
		c. Utility networks
		d. Waste disposal
D. Ecological relationships		a. Salinization of water resources
		g. Other
E. Others		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):

$$\text{WAI} = \frac{\sum fi\, wi}{\sum fi}$$

Where: *fi = frequency of respective respondents*

wi= 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_IS58thF4shtn2YKnKdeZnmDpf3CcUP6NjYH3A6Q5uICQ/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%

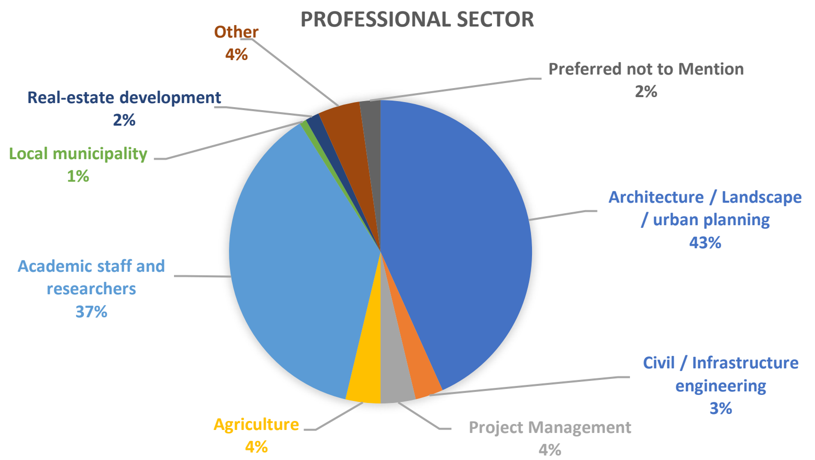


Fig. (15) Questionnaire Analysis, Question 1, Source: Author

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%

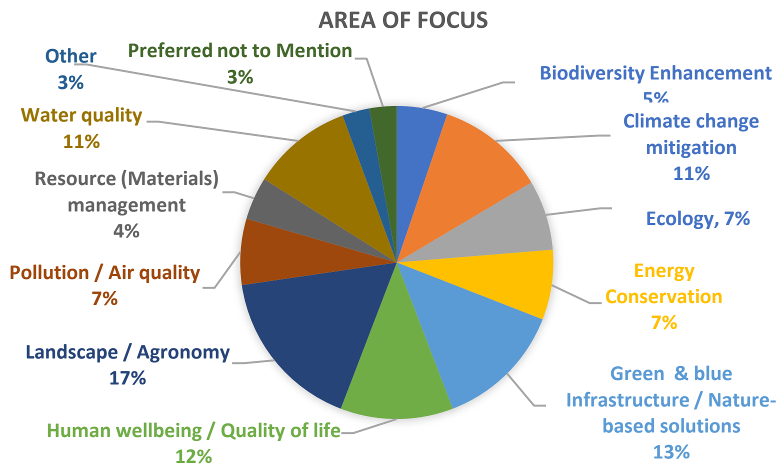


Fig. (16) Questionnaire Analysis, Question 2, Source: Author

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%

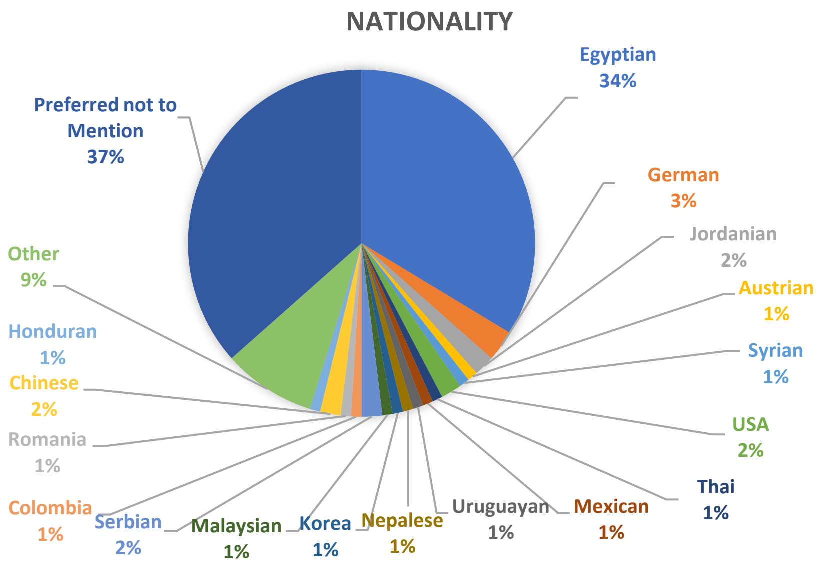


Fig. (17) Questionnaire Analysis, Question 3, Source: Author

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 = $\frac{\sum fi\ wi}{\sum fi}$

Where: *fi = frequency of respective respondents*

wi= 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%

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

$$= \sum \frac{(1*0.1)+(4*0.2)+(21*0.3)+(26*0.4)+(29*0.5)+(8*0.6)+(1*0.7)+(0*0.8)+(0*0.9)+(1*0.9)+(0*1)}{(104-10)}$$

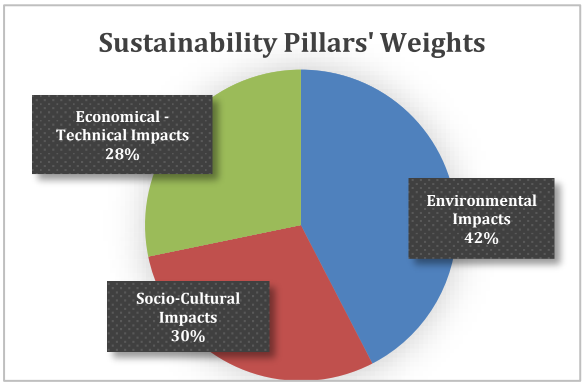
$$= \frac{39.8}{94} = \mathbf{0.4234}$$

∴ 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**



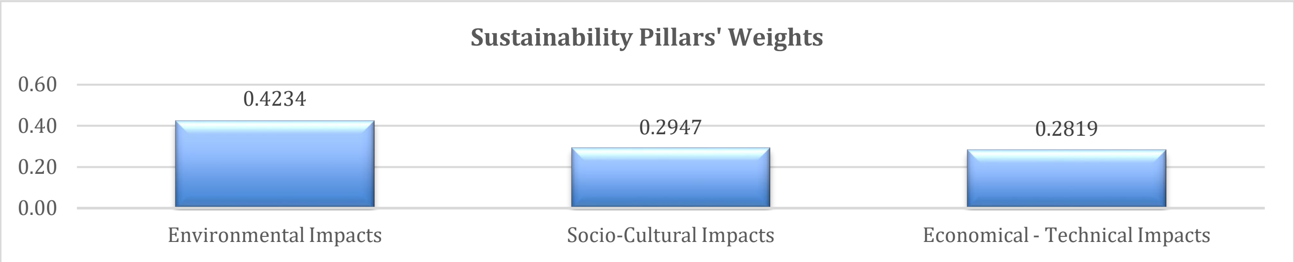


Fig. (19) Questionnaire Analysis, Main categories' weight Analysis, *Source: Author*

Objective 2- Individual Indicator Weights identification

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

$$WAI = \frac{\sum fi\ wi}{\sum fi}$$

Where: *fi = frequency of respective respondents*

wi= 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%

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

$$= \sum \frac{(0*0.2)+(3*0.4)+(22*0.6)+(37*0.8)+(38*1)}{(104-4)}$$

$$= \frac{82}{100} = \mathbf{0.82}$$

∴ 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

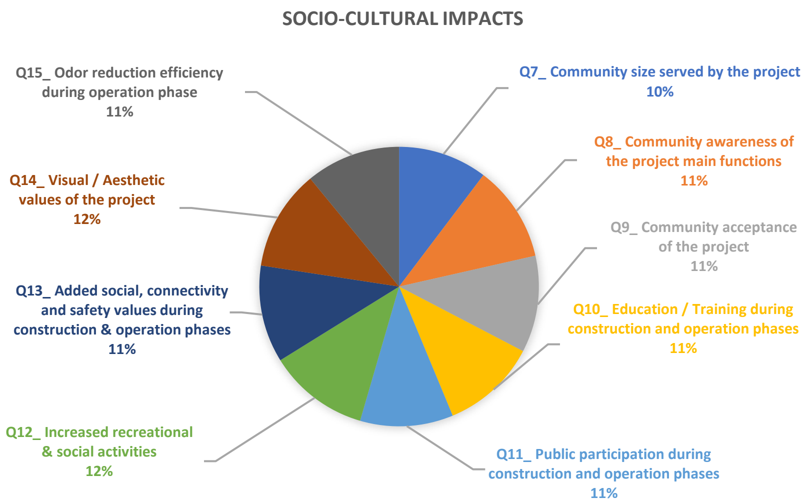


Fig. (21) Questionnaire Analysis, Qs 7 to 15, Socio - Cultural indicators' weights, Source: Author

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

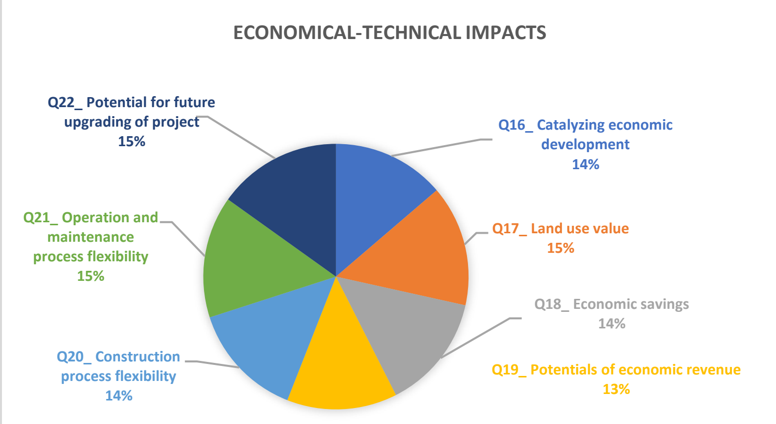


Fig. (22) Questionnaire Analysis, Qs 16 to 22, Economic - Technical indicators' weights, Source: Author

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

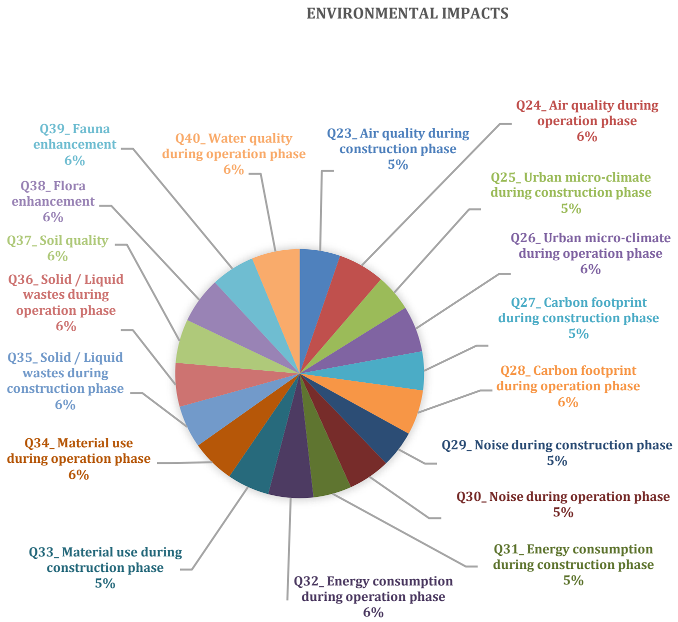


Fig. (23) Questionnaire Analysis, Qs 23 to 40, Environmental indicators' weights, Source: Author

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* = $\sum \frac{Category\ impact\ Score}{Max\ Score} * Categore\ Weight) * 10$

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.

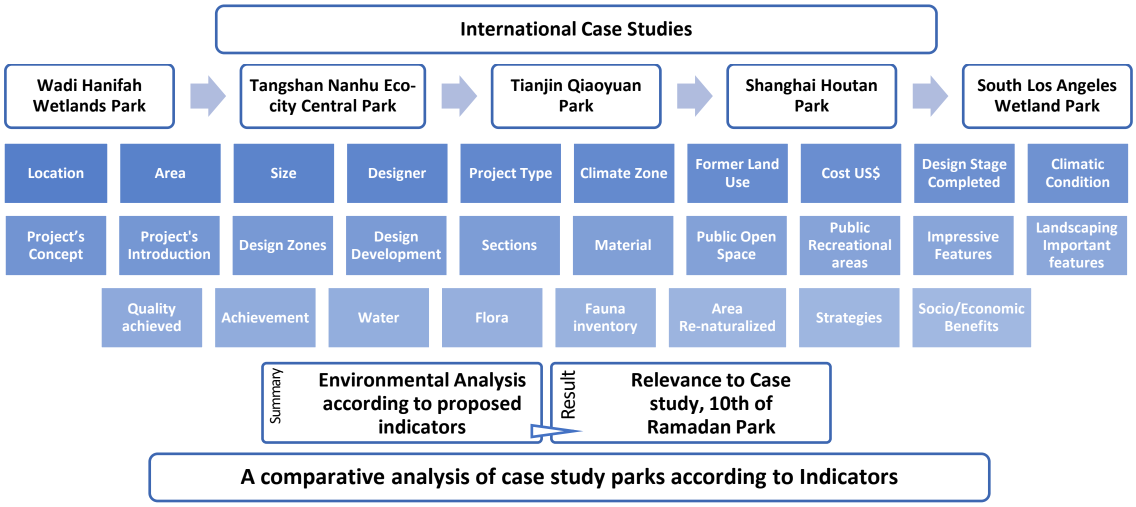


Fig. (29) Chapter 4, Methodology and structure, Source: Author

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 km^2

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$ **Design Stage Completed**	160 million, Budget: $1 billion 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	1. Environmental and sustainable Approach 2. Water demand management 3. Land use and activities 4. Rehabilitation of the valley 5. Controlling and conditions
Introduction	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 m^3 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)
Design Zones	 *Fig. (32) Five design Zones make up the Wadi Hanifa Project, Source Alrabe, M., 2015, edited by Author*

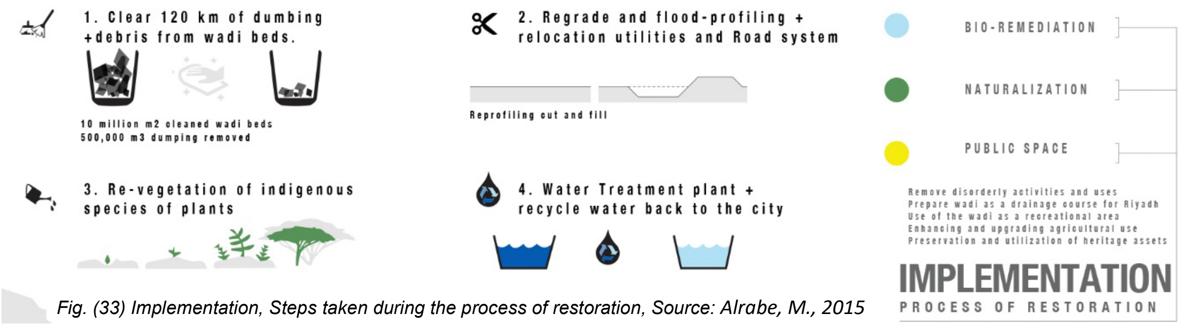


Fig. (33) Implementation, Steps taken during the process of restoration, Source: Alrabe, M., 2015

Design Development

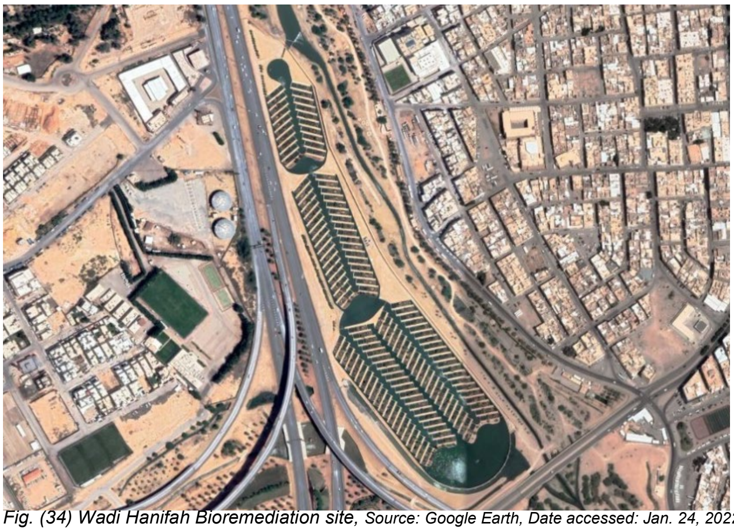
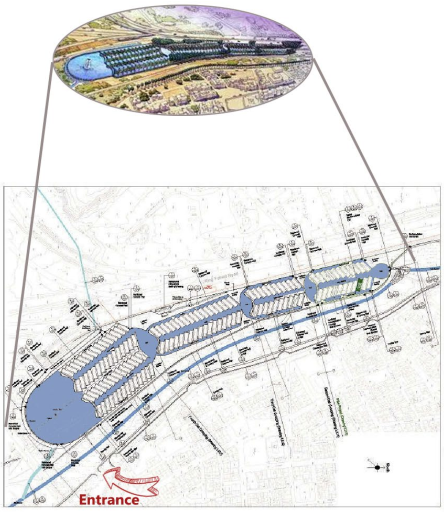


Fig. (34) Wadi Hanifah Bioremediation site, Source: Google Earth, Date accessed: Jan. 24, 2022

The bio-remediation system now has **three compartments**, while there were four in the original design, d*ue 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)



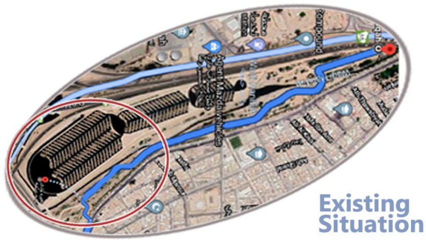


Fig. (35) Existing situation, Source: Author from Stockton, G., et al., 2010, RCRC, Google Map, Date accessed: June 2020

Sections

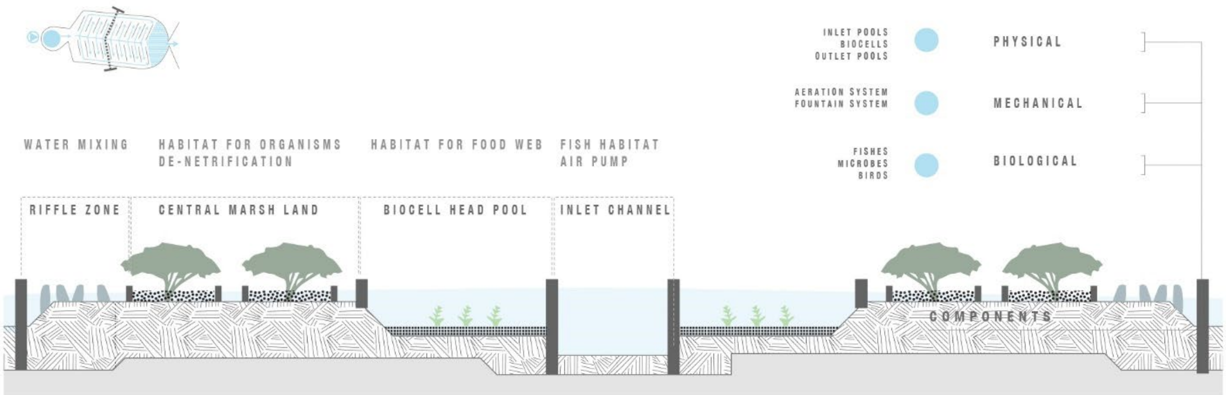


Fig. (36) Bioremediation Components section, Source: Alrabe, M., 2015

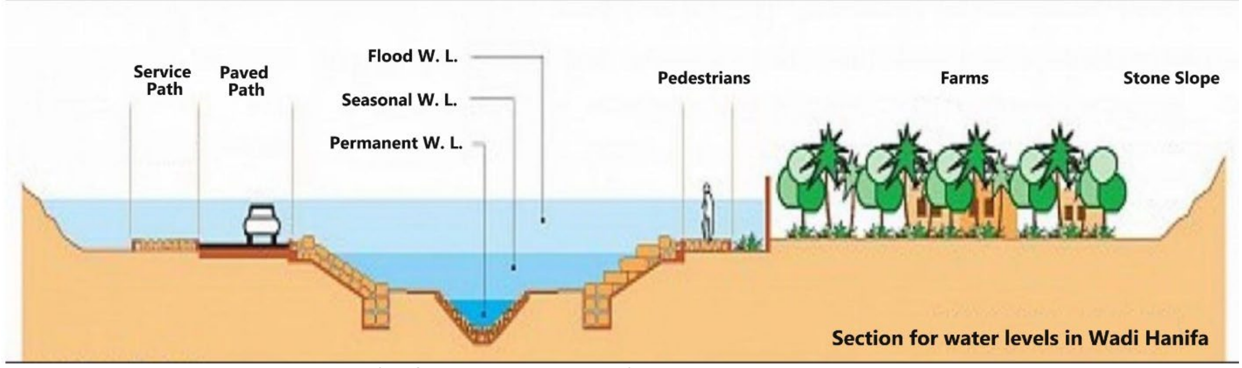


Fig. (37) Water levels section in Wadi Hanifah, Source: Edited by Author from https://www.alriyadh.com/518208, 2010, Date accessed: June 19, 2020

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) (Samhouri, 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. (Samhouri, 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. (Samhouri, 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. (Samhouri, W., 2010)

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

Achievement

BEFORE

AFTER

Fig. (42) Wadi Hanifah location before construction, *Source: LPS-CSB-1015, 2015* *Fig. (43) Park after Construction*

Water

- 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

5 lakes created (25.1 hectares total surface area)

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

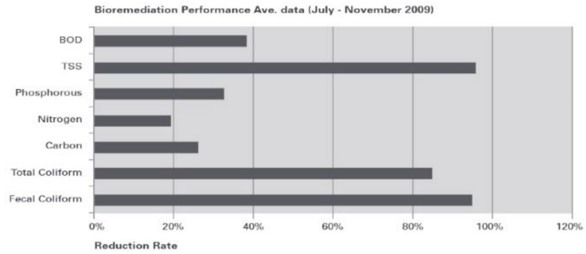


Fig. (44) Bioremediation performance in 2009, Source: Arriyadh DA/Moriyama & Teshima/Buro Happold, 2010

Flora

- 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

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 (Trottier, J., et al., 2015)

Area Re-naturalized

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%**
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)

Strategies

Environmental Strategies:

- 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

Social Strategies

- Promote Green Space for Public Recreation

Economic Strategies

- Reduce economic hardship at the community level
- Combining economic growth with environmental conservation (Al-Obaid, S., et al., 2017)

Socio/Economic Benefits

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.
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)

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	• 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	• 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	• 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 m^3 (2010) • Urban wastewater cleansed/day, 1,200,000m^3 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 km^2

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 km2, 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$ **Completion**	$68,027,648 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)

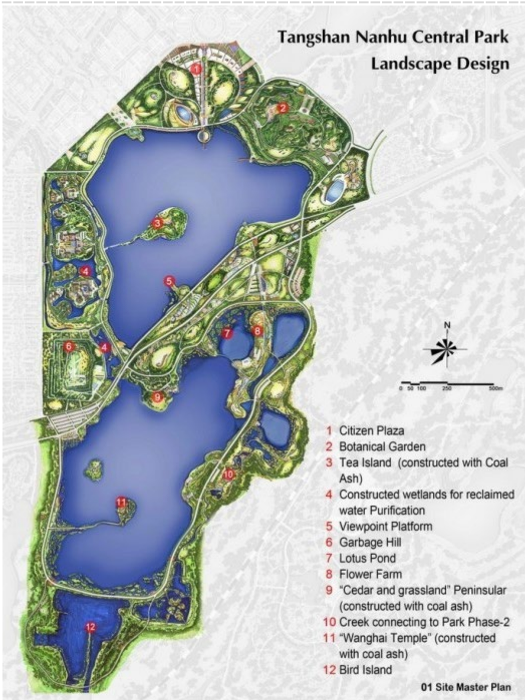


Fig. (47) Park's Landscape Design, Source: LPS-CSB- 494, 2012

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; Biennal, 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)

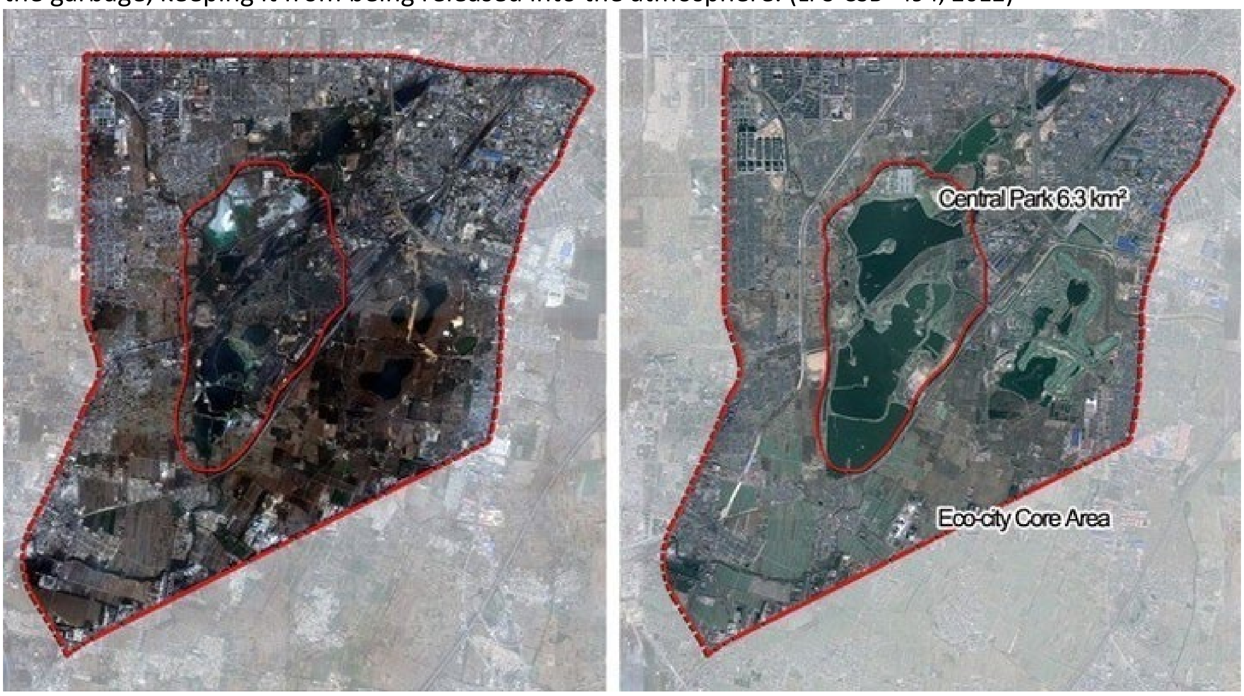


Fig. (49) Park's Satellite Images: Left - Prior to Construction on 08-07-2008, Right - Following Completion on 11-15-2010
Source: LPS-CSB- 494, 2012; Beijing Tsinghua Urban Planning & Design Institute

Analysis

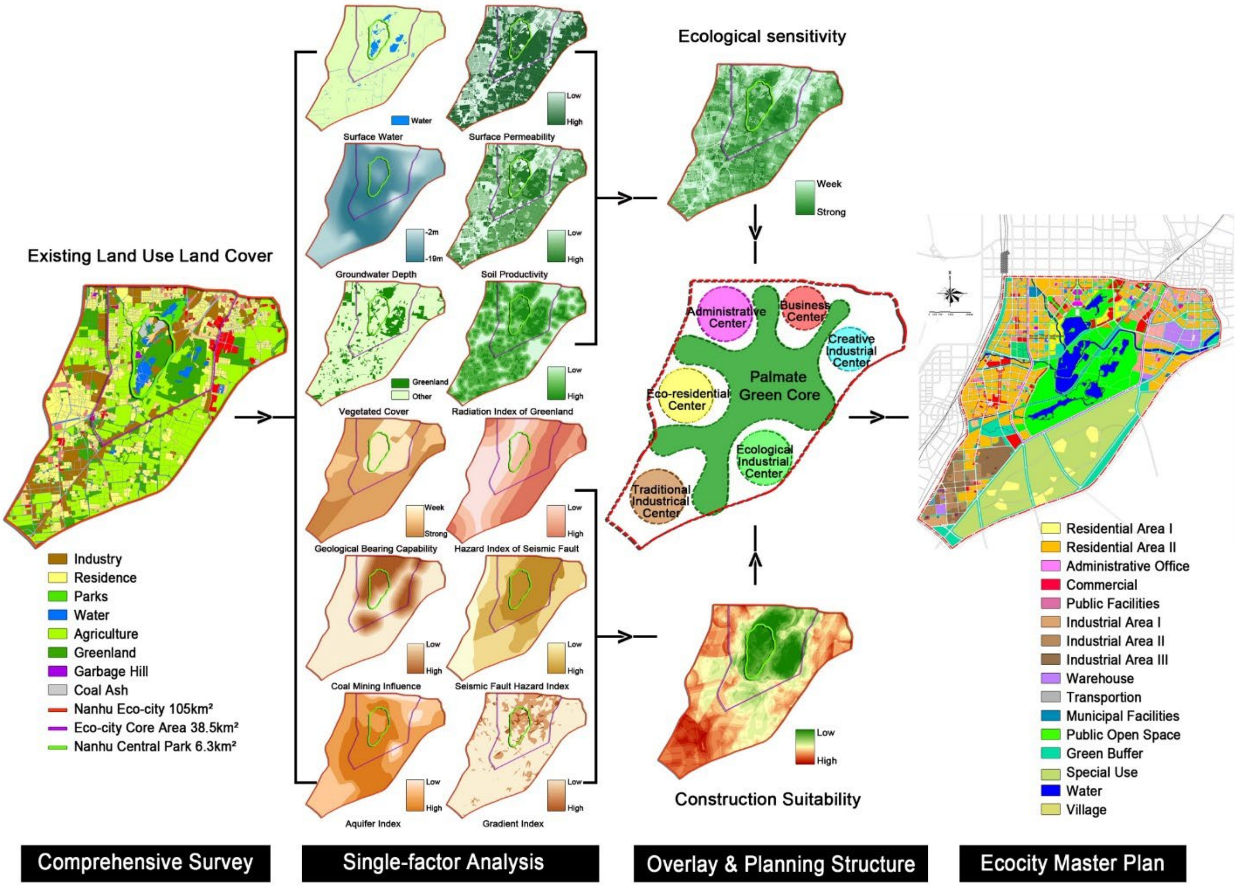


Fig. (50) GIS Overlay study: To define a stable foundation for land development in the ecocity region, a detailed GIS Overlay study was used. Source: Biennal, An, Y., et al., 2014

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.

In the garbage hill, a waste gas collection system captured and burnt the gas produced by the garbage, which prevented its release into the atmosphere.

(LPS-CSB- 494, 2012)

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

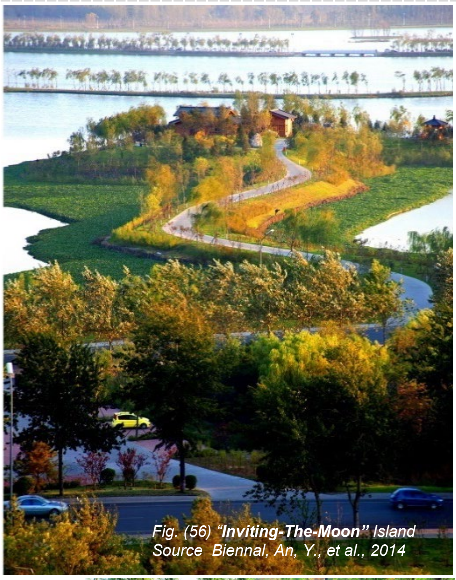


Fig. (56) "Inviting-The-Moon" Island
Source Biennal, An, Y., et al., 2014

• "**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

Quality achieved:

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)

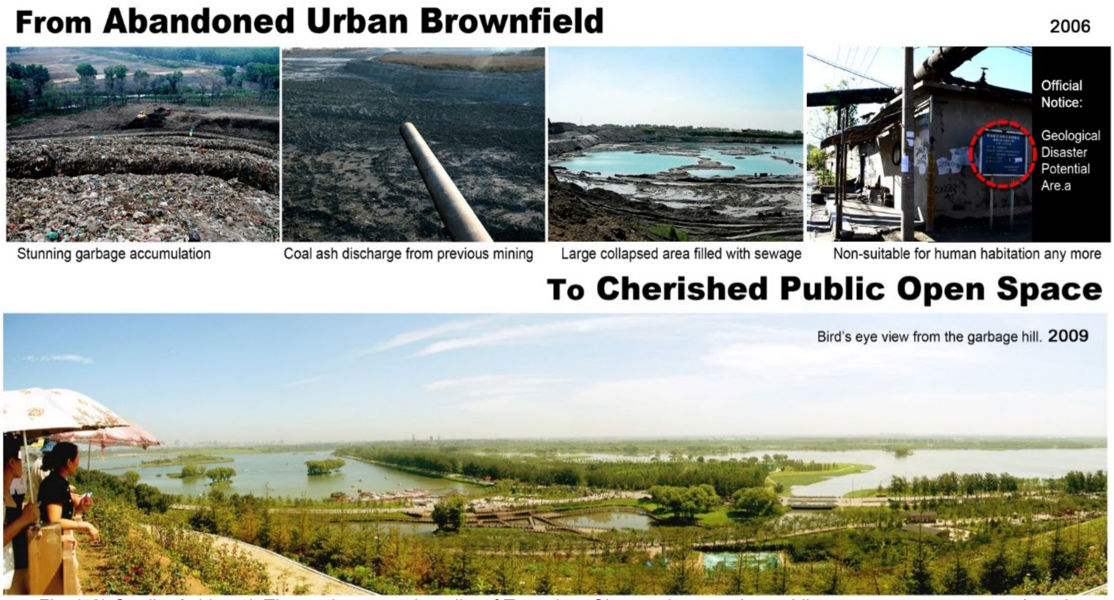


Fig. (58) Quality Achieved: The environmental quality of Tangshan City was improved, a public open space was created, and habitats for urban wildlife were rehabilitated, Source: Biennal, An, Y., et al., 2014; ULI Americas, 2013

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

Achievement

BEFORE

Fig. (59) Formerly Coal mining site,

AFTER

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 m^3 of reclaimed water is received daily by the south lake. The north lake is replenished daily with 20,000 m^3 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 CO_2, 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)

Fauna inventory

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

- 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)

Strategies

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

Socio/Economic Benefits

<u>SOCIAL</u>

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

<u>ECONOMIC</u>

- **Material costs saving** of $47.2 million through utilization of 6 million m^3 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)

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	• 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.
		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	• 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 km^2

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

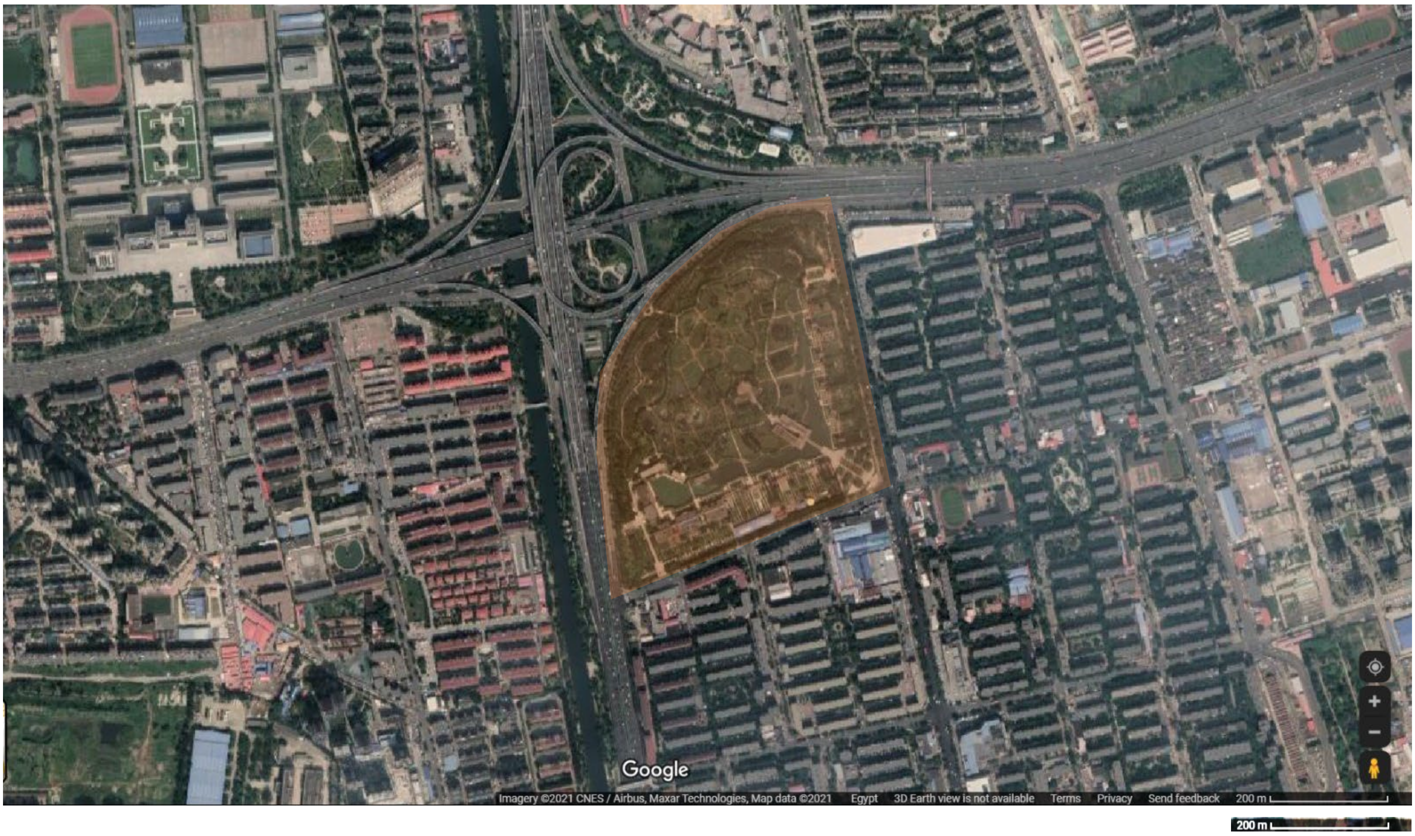


Fig. (64) Tianjin Qiaoyuan Wetland Park's Location, Source: Google Map, edited by Author, Date accessed: Sep. 1, 2021

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

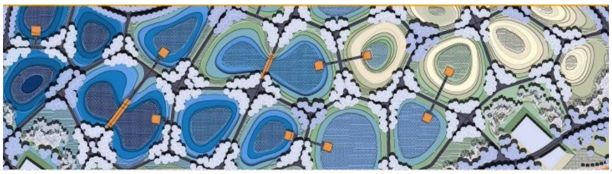


Fig. (67) Pond Cavities design Zones, Source: Cyclifier, 2013

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

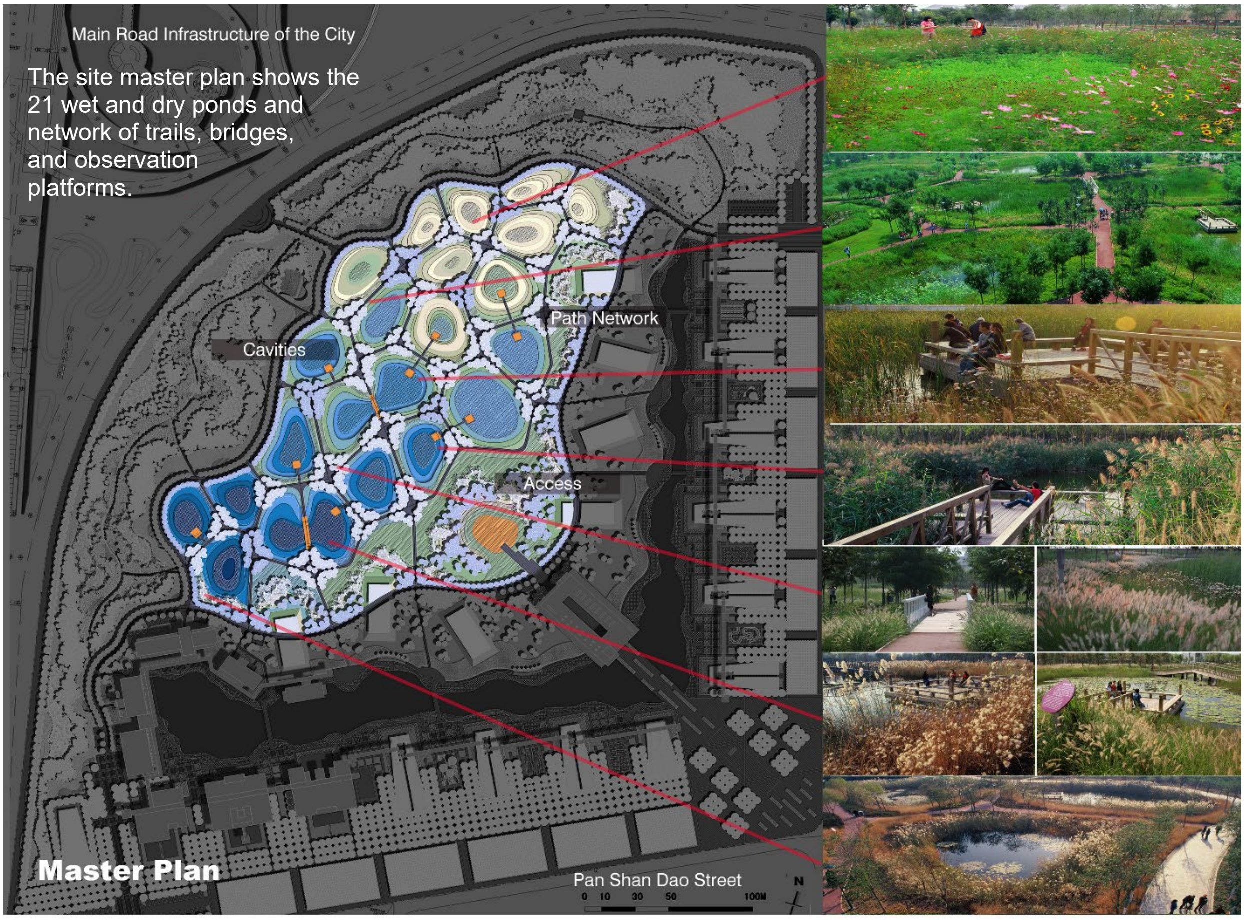


Fig. (69) Park's Site Plan for the various ponds, Source: Turenscape, 2009

Design Development

Fig. (70) 21 Ponds and trails, Source: LPS-CSB- 425, 2011

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.

Section

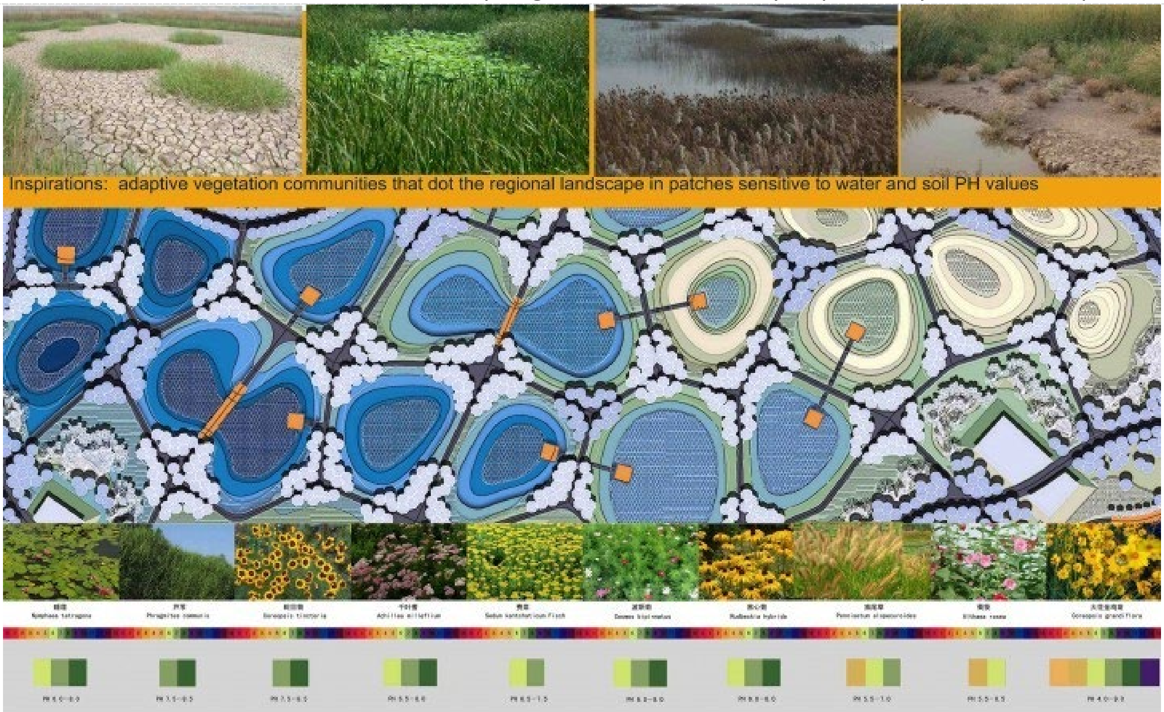


Fig. (71) Site condition, Source: Turenscape, 2009

"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)

Material

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)

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)

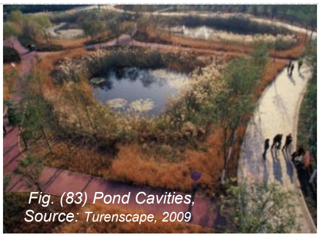


Fig. (83) Pond Cavities, Source: Turenscape, 2009

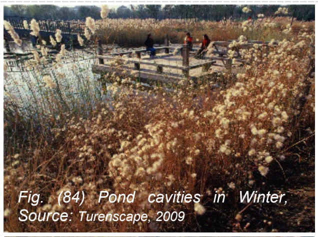


Fig. (84) Pond cavities in Winter, Source: Turenscape, 2009


Fig. (85) Pond cavities in Summer, Source: Turenscape, 2009

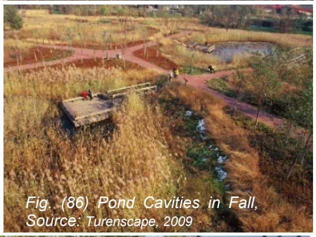


Fig. (86) Pond Cavities in Fall, Source: Turenscape, 2009

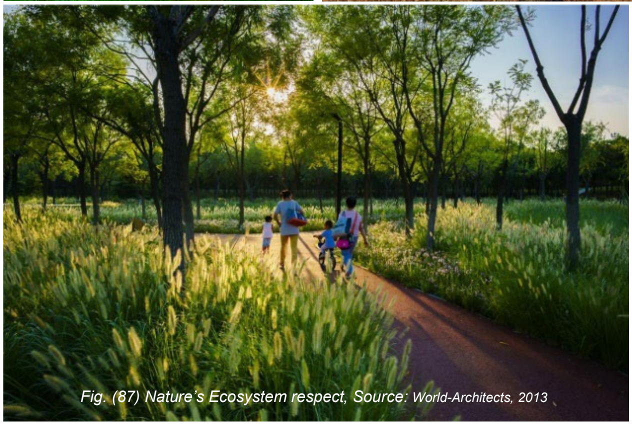


Fig. (87) Nature’s Ecosystem respect, Source: World-Architects, 2013

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)

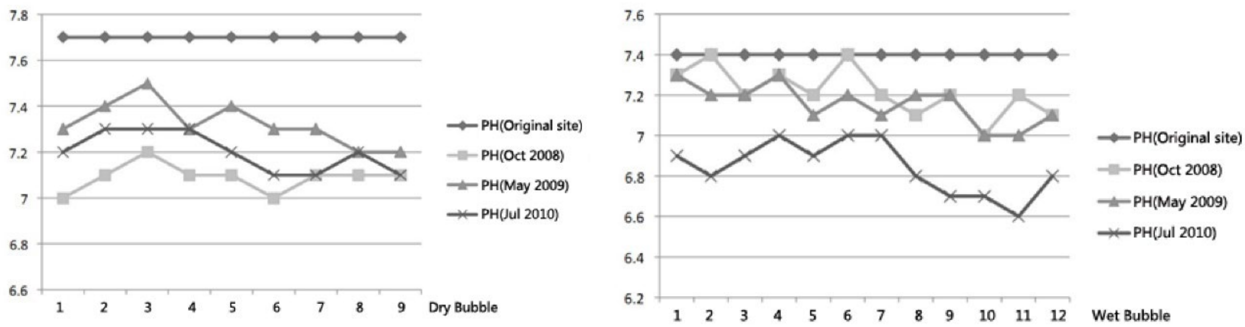


Fig. (88) Bubble’s Soil Sample for wet and dry ponds, Source: Rottle, N., & Lacson, 2011

Achievement

BEFORE

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

AFTER

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

(LPS-CSB- 425, 2011)

Water

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.

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

Strategies

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

Social Strategies

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

Economic Strategies

- Low Cost

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

Socio/Economic Benefits

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.

(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.
	Biodiversity. Habitat Diversity	Flora (Vegetation)	- Number of Fauna and Flora species introduced into the habitat	Quantitative	• 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 km^2

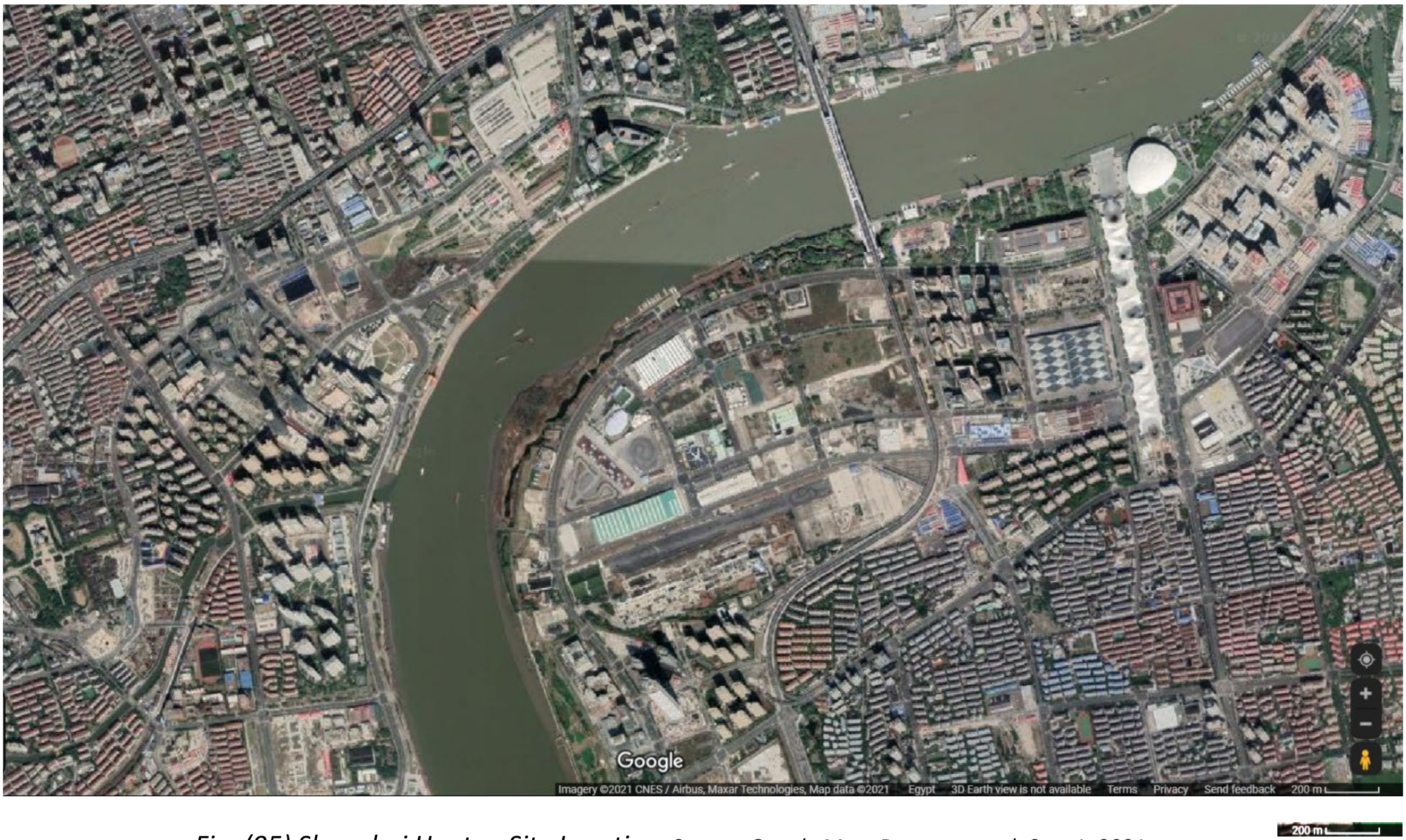


Fig. (95) Shanghai Houtan Site Location, *Source: Google Map, Date accessed: Sep. 1, 2021*

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 m2 ,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$	$15.7 million
Completed	2010

Challenges and Site Condition

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)

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

Project's Concept

- 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"

(LPS-CSB- 424, 2011; Yang, Y., et al., 2016)

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

Introduction

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)

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 aeriation, 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

Section

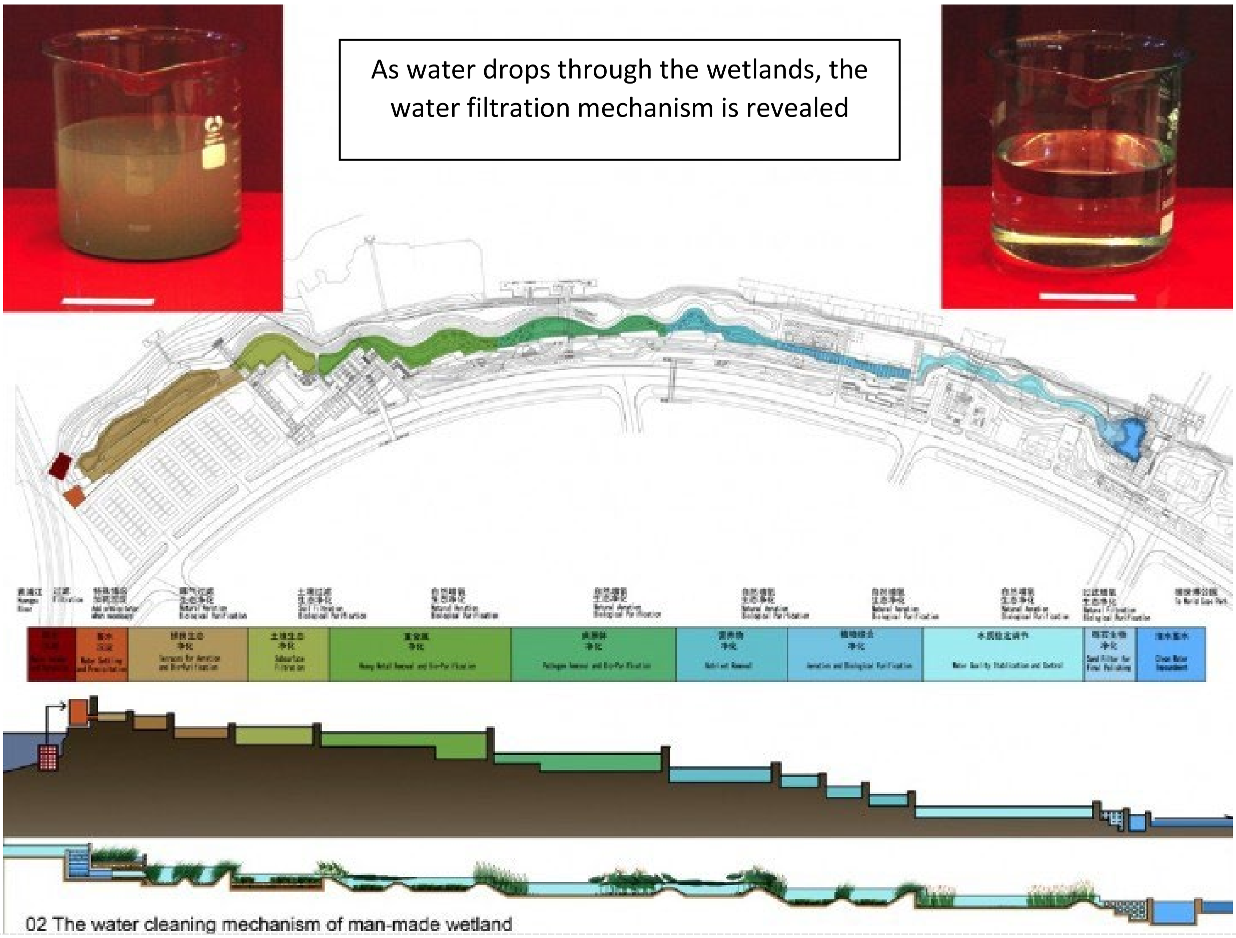


Fig. (102) The water quality, Source: Turenscape, 2017; LPS-CSB- 424, 2011

Material

- 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.
- 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

Public Open Space

- 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.
- 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

- 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.

Public Recreational areas

- 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)

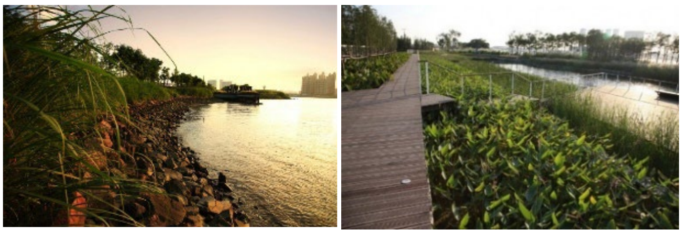


Fig. (107) Riprap and terraced wetland, Source: LPS-CSB- 424, 2011

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)

Achievement

BEFORE

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

AFTER

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)

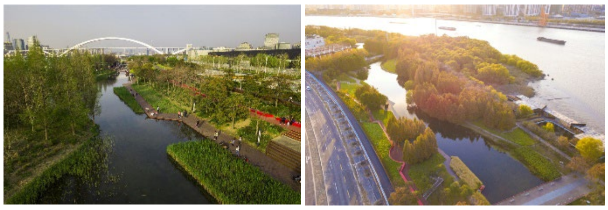


Fig. (111) Ecological process for water treatment, Source: Turenscape, 2017

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)

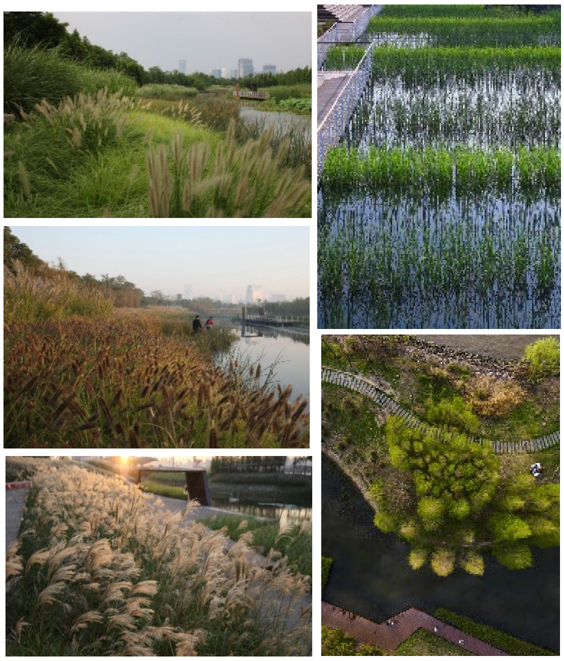


Fig. (112) Biodiversity Enhancement, Source: Turenscape, 2017

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

Strategies

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

Social Strategies

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

Economic Strategies

- Low-Cost Maintenance

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

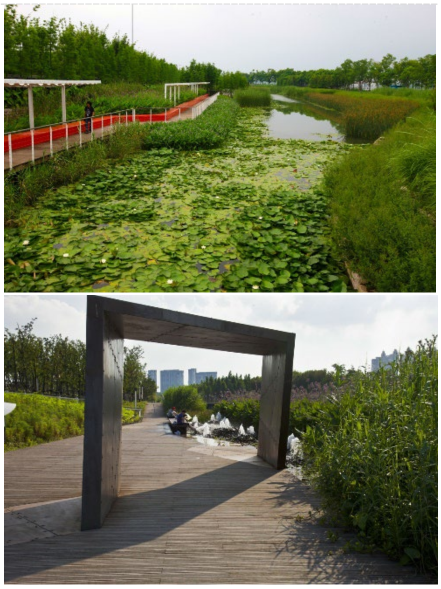


Fig. (114) Better City, Better Life, Source: Turenscape, 2017

Socio/Economic Benefits

<u>SOCIAL</u>

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.

<u>ECONOMIC</u>

- 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**	- **Air quality:** Improvement in air quality due to increased vegetation cover	Quantitative	• Sequesters an estimated 242 tons of carbon annually in park's extensive wetlands, perennial plantings, and trees.
		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	• 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	- **Quality/ Quantity of wastes:** % of waste materials discharged during the treatment process	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	**- 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	Increased the biodiversity of the site dramatically, with 93 species of plants
		Fauna	- Number of Fauna and Flora species introduced into the habitat	Quantitative	over 200 species of animals observed.
	Water	**Water Reused**	- **Water Reused**: % of water reused or reintroduced to the irrigation system.	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	- **Water quality:** % of pathogens removed through the constructed wetland	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 continues 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 km^2

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 m2, 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$	$12.4 million
Completed	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)
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. (117) LA Park wetland, Source: LAParks, 2022

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

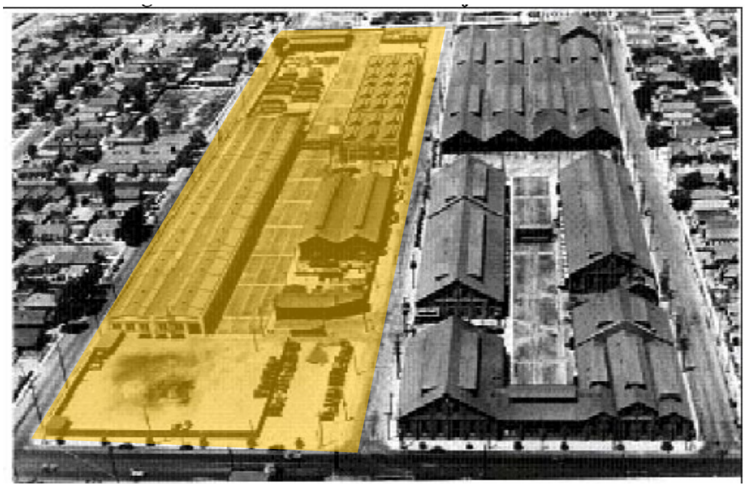
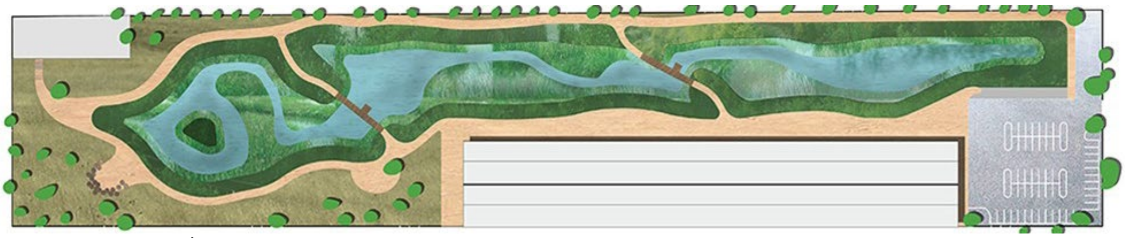


Fig.(119) Aerial view of intended Wetlands Park's site circa 1930s., Source: Preliminary Design Report, 2008, edited by Author

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)

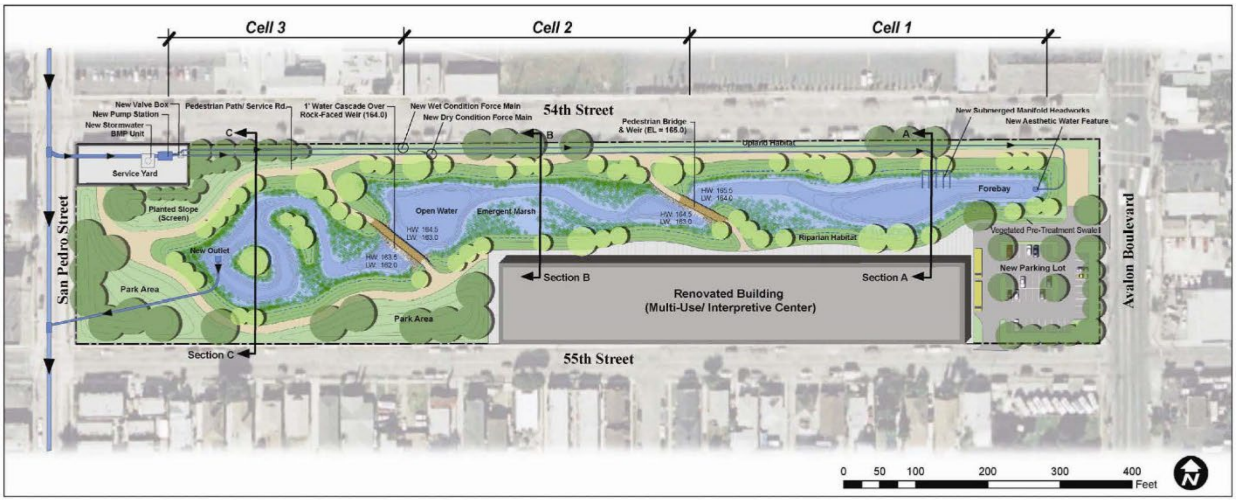


Fig. (121) Wetlands Park Site Layout proposal, Source: Draft EIA report, 2007 edited by Author

Design Zones

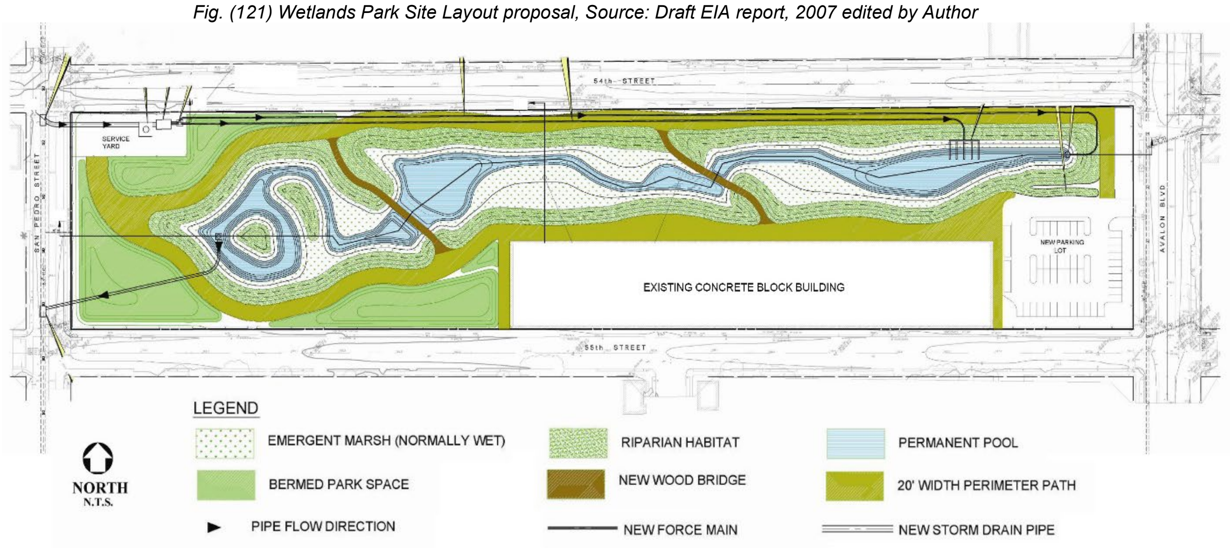


Fig. (122) Wetlands Park preliminary Site Plan proposal, Source: Draft EIA report, 2007

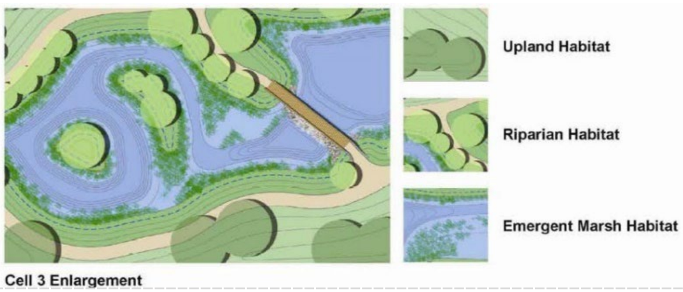


Fig. (123) Wetlands Park preliminary Site Plan proposal for Cell 3, Source: Draft EIA report, 2007

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)

Sections

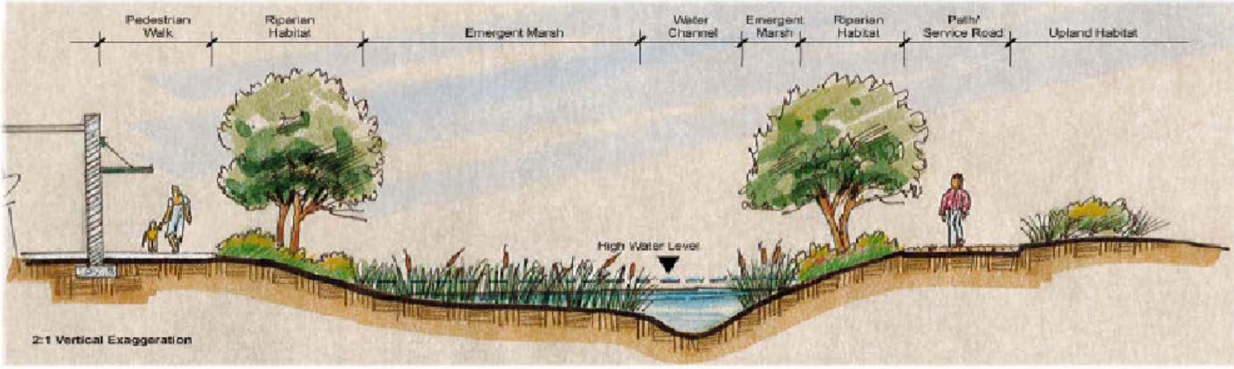


Fig. (125) Wetlands Park conceptual Section rendering, Source: Draft EIA report, 2007

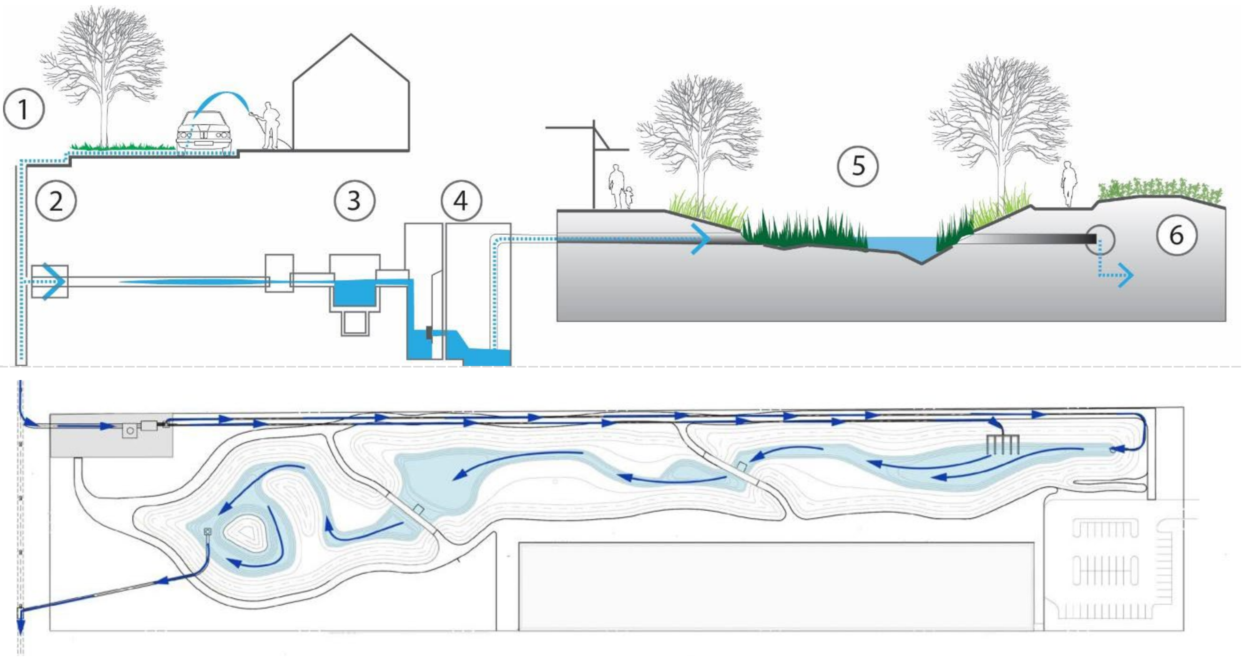


Fig. (126) Wetlands Park stormwater runoff treatment design, Source: Shannon, K., et al., 2016

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.

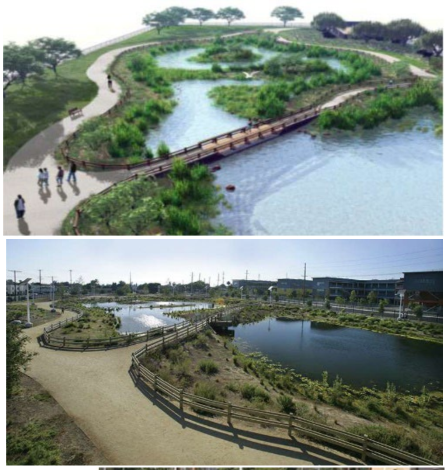
- Visitors are educated about wetland ecosystems, native habitat and species of California, and physical and biological phenomena specific to wetlands.
- In the north-south direction, wooden bridges traverse the constructed wetlands and provide gathering places for diverse groups of residents and youngsters.
- 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.

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

- 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)

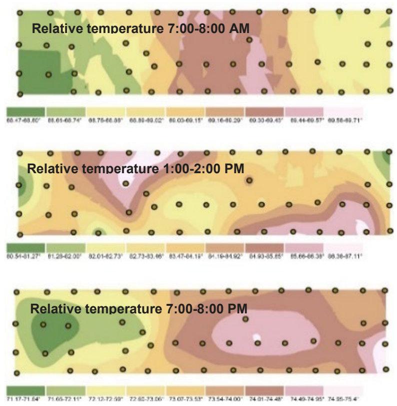


Fig. (134) Relative Temperature study, Source: Shannon, K., et al., 2016

Achievement

BEFORE

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

AFTER

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-leafed 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)

Socio/Economic Benefits

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.

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	• 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	• 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	• 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
Background		Location	Riyadh	Tangshan, Hebei, China	Tianjin, China	Shanghai, China	South Los Angeles
Background		Climate	Arid	Humid continental	Cold semi-arid	Humid subtropical	Hot-summer Mediterranean
Background		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
Background		Area	**Large-scale Parks** 15,009,790 m^2 15 million square meters, 3,709 acres, **15 km^2**	**Large-scale Parks** 6,300,955.4 m^2 6.3 million square meters, 1,557 acres, **0.63 km^2**	**Medium-scale Parks** 218,530 m^2, 54 acres, **0.22 km^2**	**Medium-scale Parks** 139,616.55 m^2 34.5 acres,**0.14 km^2**	**Small-scale Parks** 36,421.7 m^2 9 acres, **0.36 km^2**
Background		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
Background		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
Background		Cost	160 million, Budget: $1 billion	$68,027,648	14.1million	$15.7 million	$12.4 million
Background		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 89,144.9 lbs of atmospheric carbon annually **Total new vegetated area = 149.8 acres, Percentage = 4.0%**	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.	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 8,997m2 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.
Environmental Aspects	Climatic Aspects	Urban Micro-Climate					
Environmental Aspects	Climatic Aspects	Carbon Footprint					
Environmental Aspects	Sustainability	Energy	No Data Available	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.
Environmental Aspects	Sustainability	Materials	• 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	• 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.	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	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.
Environmental Aspects	Sustainability	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.	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.
Environmental Aspects	Sustainability	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	No Data Available	No Data Available

	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.	• 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
	Biodiversity; Habitat Diversity	**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.	• 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**	•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 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.	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	**Water Quality**					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	•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	•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.	•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.	•Minimal maintenance save over $19,000 in annual maintenance costs •Reusing 84.5m^3 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	•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.	•Adds $243.43 /ft^2 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 /ft^2 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.

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.

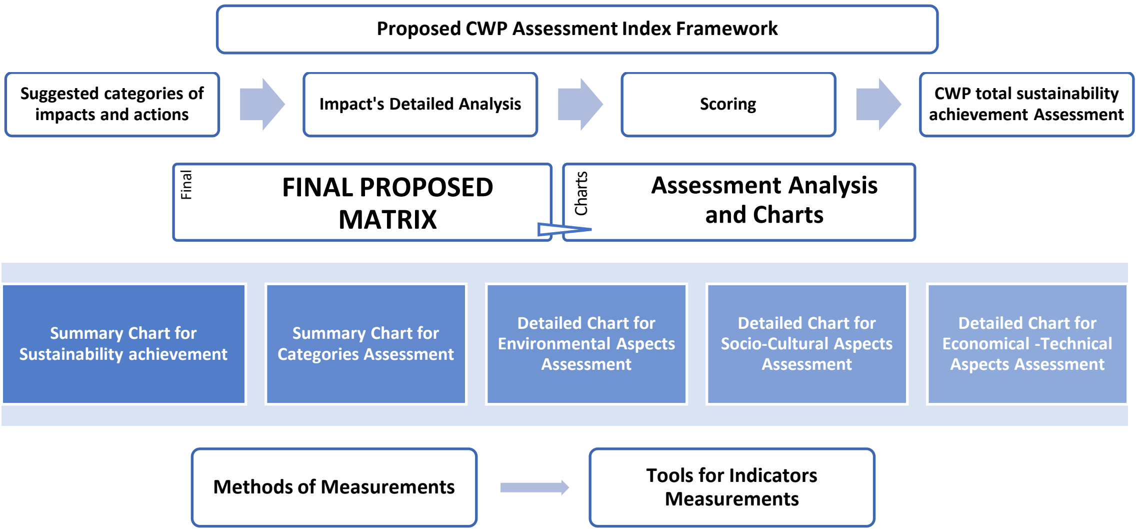


Fig. (142) Chapter 5, Methodology and structure, Source: Author

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	
Category		Impact Factors	Construction Phase	Operation Phase
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)

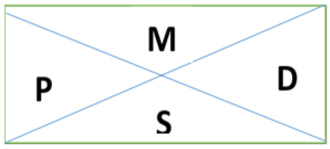


Fig. (143) Cell of proposed Matrix, Source: Author

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:

Impact **V**alue Relevance for each Factor (**IV**) = M * S * P * D Equation (1)
Environmental **I**mpact **V**alue (**EIV**) = $\sum_{i=1}^{n} Mi * Si * Pi * Di$ Equation (2)
Ratio of Impact Factor from total (**R**) = $IV/_{EIV}$ Equation (3)
The IV Weight Relevance Value (**IVWR**) = $R * FW$ 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:

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

Where:

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

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

5.2 Final proposed Matrix

Table (13) Proposed Matrix, Source: Author

Impacts / Activities			Project's Activities											
			Construction Phase						Operation Phase					
	Category	Impact Factors (IF)	Construction Phase Assessment	IV= Impact Value relevance S*M*P*D	Impact Factor Ratio R= IV/EIV	Weight Based on Questionnaire	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 Questionnaire	IV Weight Relevance (IVWR)	Percentage Achieved
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					
Category		Impact Factors (IF)	Construction Phase Assessment	IV= Impact Value relevance S*M*P*D	Impact Factor Ratio R= IV/EIV	Weight Based on Questionnaire	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 Questionnaire	IV Weight Relevance (IVWR)	Percentage Achieved
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	0.00%
		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.

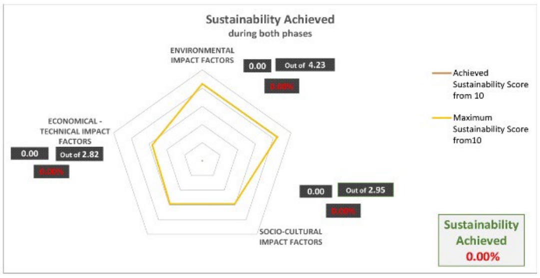
5.3.1 Summary Chart for Sustainability achievement

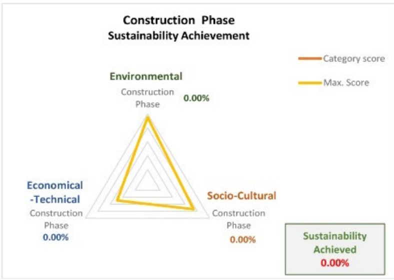
Fig. (144) Park's Sustainability achievement Chart, Source: Author

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	Sustainability: Maximum Sustainability Score from10	Percentage Achieved
1	Environmental Impact Factors	**0**	**2702**	0.4234	0.00	4.23	**0.00%**
2	Socio-Cultural Impact Factors	**0**	**1988**	0.2947	0.00	2.95	**0.00%**
3	Economical -Technical Impact Factors	**0**	**1317**	0.2819	0.00	2.82	**0.00%**
	Total Impact Assessment			1.00	0.00	10	0.00%

nr.		Category	Category score	Max. Score	%	Phase Weight	Category Total Score	Max Score	Percentage Achieved
1	Environmental Impact Factors	Construction Phase	0	2375	0.00%	0.074	**0**	**2702**	**0.00%**
2		Operation Phase	0	2525	0.00%	0.926			
3	Socio-Cultural Impact Factors	Construction Phase	0	1850	0.00%	0.074	**0**	1988	**0.00%**
4		Operation Phase	0	1850	0.00%	0.926			
5	Economical - Technical Impact Factors	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%



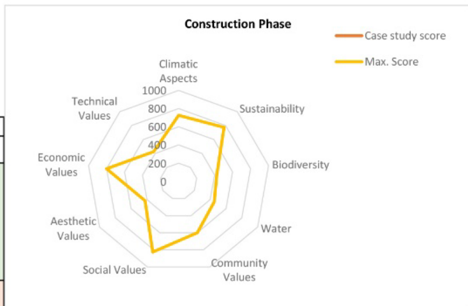


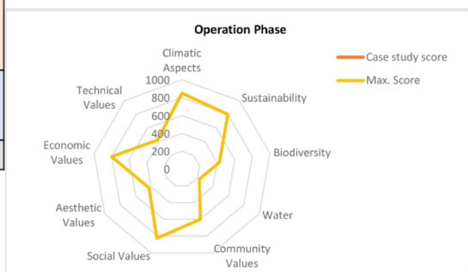
5.3.2 Summary Chart for Categories Assessment

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

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

			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	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	Socio-Cultural Impact Factors	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	Economical - Technical Impact Factors	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%





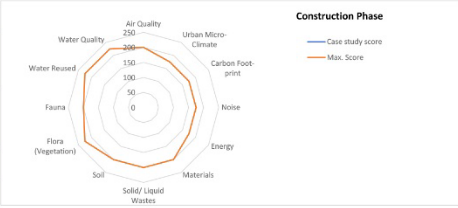
5.3.3 Detailed Chart for Environmental Aspects Assessment

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

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

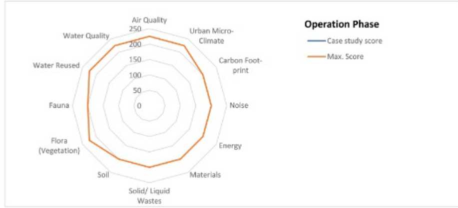
Construction Phase

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	Environmental Impact Factors	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			Noise	0	0	0	0	0	0.7	0	175	0.00%			
5		Sustainability	Energy	0	0	0	0	0	0.7	0	175	0.00%	0	775	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			Soil	0	0	0	0	0	0.8	0	200	0.00%			
9		Biodiver sity	Flora (Vegetation)	0	0	0	0	0	0.9	0	225	0.00%	0	425	0.00%
10			Fauna	0	0	0	0	0	0.8	0	200	0.00%			
11		Water	Water Reused	0	0	0	0	0	0.9	0	225	0.00%	0	450	0.00%
12			Water Quality	0	0	0	0	0	0.9	0	225	0.00%			
Total Environmental Value										0	2375		**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	Environmental Impact Factors	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			Noise	0	0	0	0	0	0.8	0	200	0.00%			
5		Sustainability	Energy	0	0	0	0	0	0.8	0	200	0.00%	0	800	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			Soil	0	0	0	0	0	0.8	0	200	0.00%			
9		Biodivers ity	Flora (Vegetation)	0	0	0	0	0	0.9	0	225	0.00%	0	425	0.00%
10			Fauna	0	0	0	0	0	0.8	0	200	0.00%			
11		Water	Water Reused	0	0	0	0	0	0.9	0	225	0.00%	0	450	0.00%
12			Water Quality	0	0	0	0	0	0.9	0	225	0.00%			
Total Environmental Value										0	2525		**0**	**2525**	**0.00%**



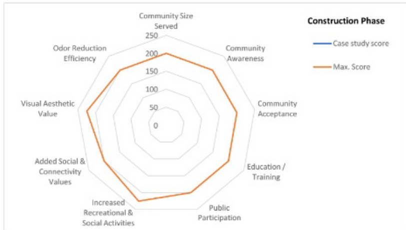
5.3.4 Detailed Chart for Socio-Cultural Aspects Assessment

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

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

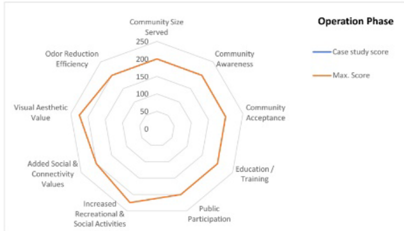
Construction Phase

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 Values	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			Added Social & Connectivity Values	0	0	0	0	0	0.8	0	200	0			
20		Aesthetic Values	Visual Aesthetic Value	0	0	0	0	0	0.9	0	225	0	0	425	0.00%
21			Odor Reduction Efficiency	0	0	0	0	0	0.8	0	200	0			
Total Socio-Cultural Value										0	1850		**0**	**1850**	**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
13	Socio-Cultural Impact Factors	Community Values	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			Added Social & Connectivity Values	0	0	0	0	0	0.8	0	200	0			
20		Aesthetic Values	Visual Aesthetic Value	0	0	0	0	0	0.9	0	225	0	0	425	0.00%
21			Odor Reduction Efficiency	0	0	0	0	0	0.8	0	200	0			
Total Socio-Cultural Value										0	1850		**0**	**1850**	**0.00%**



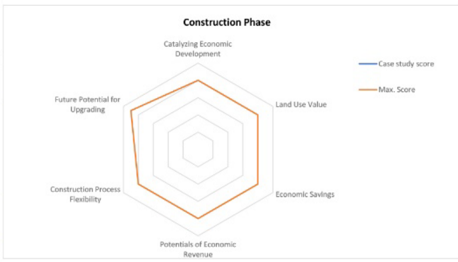
5.3.5 Detailed Chart for Economical -Technical Aspects Assessment

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

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

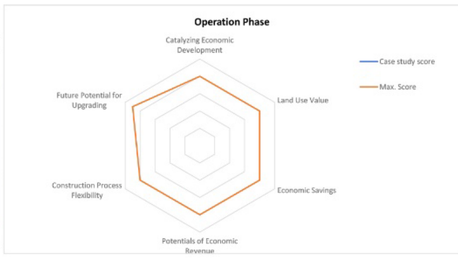
Construction Phase

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	Economical -Technical Impact Factors	Economic Values	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%			
26		Technical Values	Construction Process Flexibility	0	0	0	0	0	0.8	0	200	0.00%	0	425	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= Impact Value relevance	Factor Weight	Case study score	Max. Score	%	Total Category Score	Max Score	Percentage Achieved
22	Economical -Technical Impact Factors	Economic Values	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%			
26		Technical Values	Operation and Maintenance Process Flexibility	0	0	0	0	0	0.8	0	200	0.00%	0	425	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 metrices 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 metrices were selected according to the US Environmental Protection Agency guide, Landscape Architecture Foundation Evaluating Landscape Performance, 2018. (LAF, 2018) The metrices 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 O3, NO2, SO2, CO, and PM10. 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
		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 *If carbon markets exist, carbon sequestration and avoidance can be converted to a monetary value.* **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:** 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**	**-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	**Energy Use** **Reducing nonrenewable energy consumption** **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. **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. **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.)	US Energy Information Administration: Average Retail Price of Electricity Green Roofs for Healthy Cities: GreenSave Calculator (members only)
		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	**Reused & Recycled Materials** **Repurposing materials from the site or elsewhere** **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. **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. **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.)	California Department of Housing and Community Development: Recycled Content Value Calculations Worksheet Roadway Fill Volume, Cost, and Weight Calculator US Green Building Council LEED Existing Buildings v3 (2009): Materials and Resources Calculator
		Solid/ Liquid Wastes	**- Quality/ Quantity of wastes:** % of waste materials discharged during the treatment process	Quantitative	**Waste Reduction** **Reducing the need for off-site waste disposal** **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. **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. **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.) **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.)	EPA: Waste Reduction Model US Green Building Council LEED v4: Construction and Demolition Waste Calculator
		Soil	**- Quality/ Quantity of soil creation, preservation & restoration:** % of fertile or restored soils -Reducing erosion and sedimentation -Improving soil health through nitrogen fixation, supporting nutrient cycling or pollution reduction	Quantitative	**Soil Creation, Preservation & Restoration** **Remediating degraded soils and protecting undisturbed soils** **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. **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. **Improvement in soil infiltration rate** (change in rate) Measure infiltration time in the field using a single or double ring infiltrometer.	US Natural Resources Conservation Service (NRCS): Soil Health Assessment NRCS: Guidelines for Soil Quality Assessment in Conservation Planning American Society of Landscape Architects Landscape Architecture Technical Information Series: A Landscape Performance + Metrics Primer for Landscape Architects – Soils and Amendments (free for members)

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	**Populations & Species Richness** Supporting biodiversity 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. 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.	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
		Fauna	- **Number of Fauna species** introduced into the habitat	Quantitative	**Habitat Creation, Preservation, & Restoration** Protecting and restoring functional ecosystems **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. **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. **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. **Habitat Quality** Improving ecological integrity **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.	US Fish and Wildlife Service (FWS): Critical Habitat Mapper FWS: Find Endangered Species Xerces Society: Pollinator-Friendly Plant Lists 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

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	**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. **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. **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. **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. **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. **Annual cost savings from reduced potable water consumption** Convert the volume of potable water saved to a monetary value using the local utility rate.	US Department of Agriculture: Groundwater Recharge US Geological Survey (USGS): Groundwater Levels for the Nation Oregon Water Resources Department: How to Measure the Water Level in a Well US Environmental Protection Agency: Water Sense Water Budget Tool US Green Building Council LEED Existing Buildings v3 (2009): Water Efficient Landscaping University of California: Landscape Water Requirement Calculators
		Water Quality	- **Water quality:** % of pathogens removed through the constructed wetland	Quantitative	**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. **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. **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.	EPA: Monitoring and Assessing Water Quality EPA: Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers EPA: State-Specific Water Quality Standards EarthEcho International: EarthEcho Water Challenge

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 Values	Community Size Served	**Population served:** No. of visitors during a specific time frame	Quantitativ	• 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	Quantitativ	• 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	• 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	Social Values	Education / Training	**Increased educational values and training facilities** (number/year)	Quantitative	• 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	• 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	• 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	• 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	Aesthetic Values	Visual Aesthetic Value	**Scenic quality** and increased aesthetic / visual acceptance	Quantitativ	• 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	• Conduct a survey of site users and those who live or spend time in the vicinity to determine he 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	Quantitati	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	Quantitati	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 Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) v 3.3.3 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)** Pathfinder: Landscape Carbon Calculator 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	Recycled Content (ReCon) Tool U.S. Environmental Protection Agency 2010 Recycling and Reusing Landscape Waste Cost Calculator U.S. Environmental Protection Agency 2008
		Solid/ Liquid Wastes	- **Quality/ Quantity of wastes:** % of waste materials discharged during the treatment process	Quantitative	Waste Reduction Model (WARM) v14 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)** Universal Floristic Quality Assessment Calculator National Tree Benefits Calculator (treebenefits.com) Openlands 2015
		Fauna	- **Number of Fauna species** introduced into the habitat	Quantitative	iNaturalist California Academy of Sciences and National Geographic Society 2017 eBird Cornell Lab of Ornithology 2009
	Water	**Water Reused**	- **Water Reused**: % of water reused or reintroduced to the irrigation system.	Quantitative	Resource Conserving Landscaping Cost Calculator U.S. Environmental Protection Agency 2007
		Water Quality	- **Water quality:** % of pathogens removed through the constructed wetland	Quantitative	Long-Term Hydrologic Impact Analysis 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.

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.

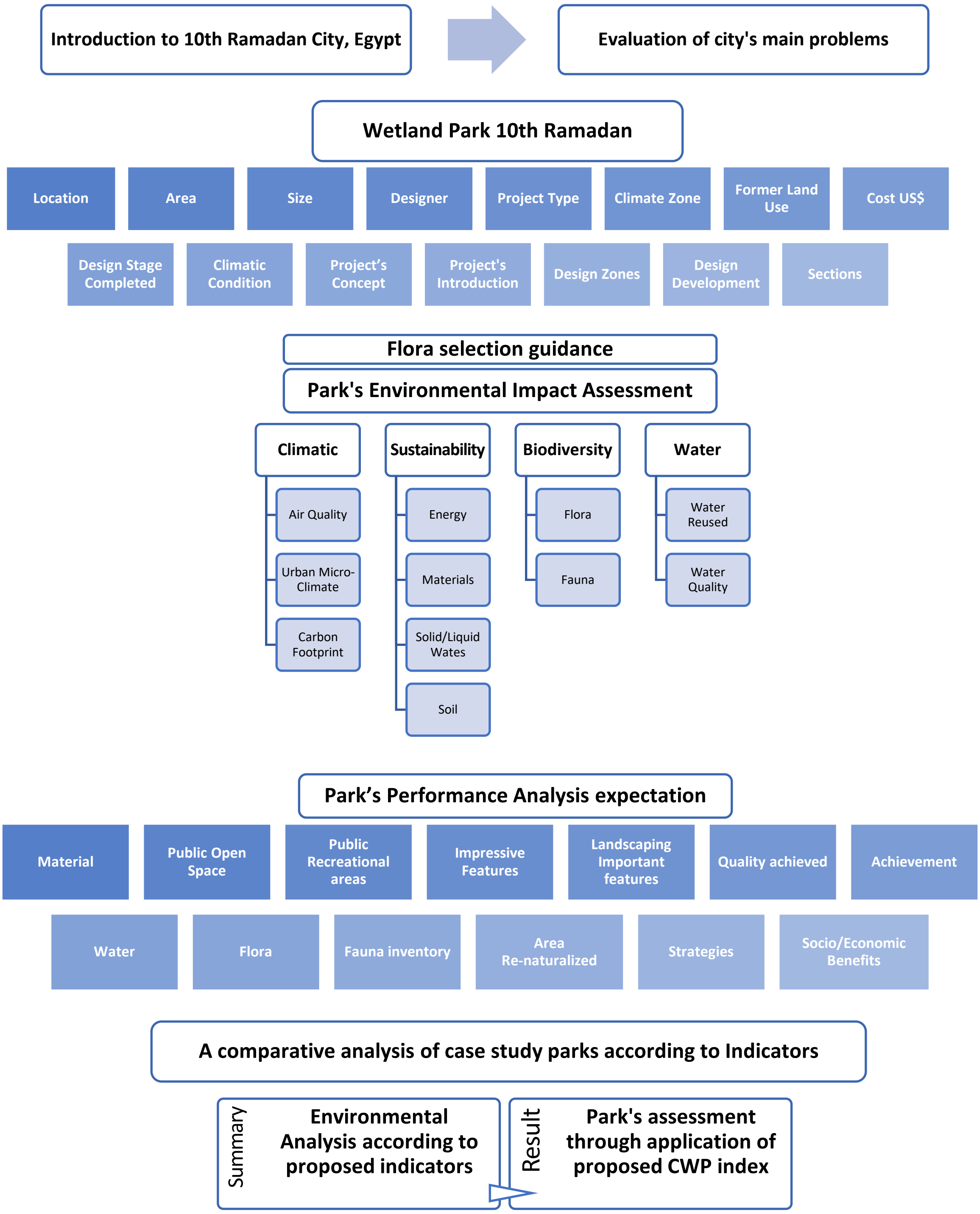


Fig. (149) Chapter 6, Methodology and structure, Source: Author

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/km2): **1400** Population living in informal settlements: **1%** Green spaces per capita (m2/person): **27.6** Land use police: **6**	4578.1 38 73.6 0-10
Transport		•				Public transport network (km/lm2): **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-Climate

Scale: **Large-scale Park;** 35 km^2

Fig. (150) 10th of Ramadan Site Location, *Source: Google Map, Date accessed: Sep. 1, 2021*

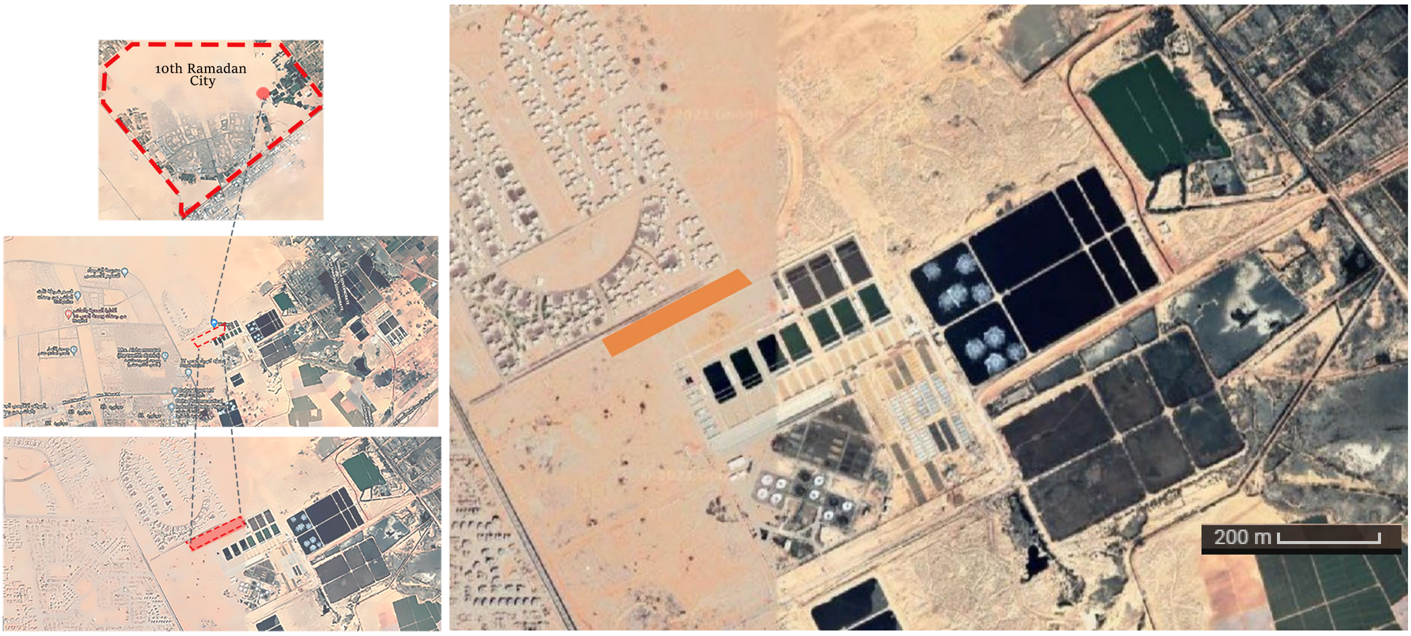
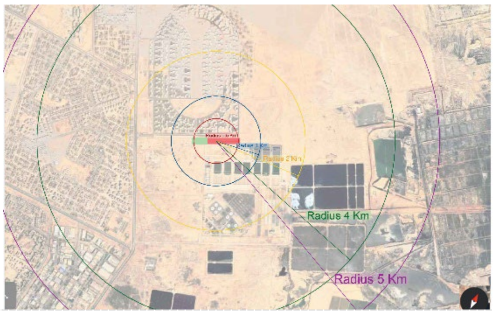
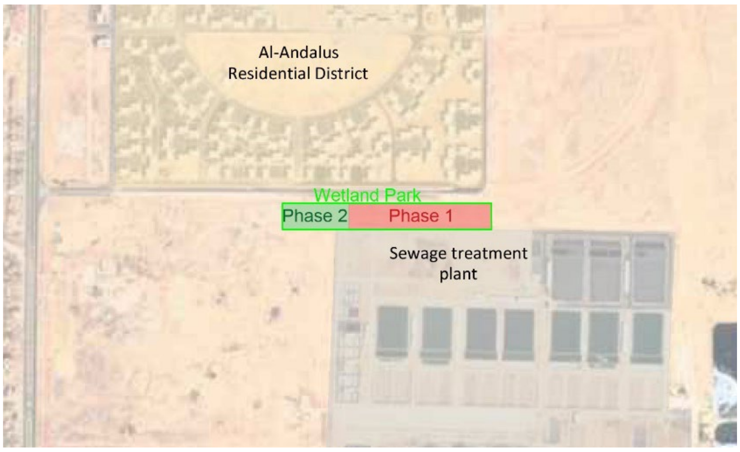


Fig. (151) 10th of Ramadan Wetland Park's Location, *Source: Google Map edited by Author, Date accessed: Sep. 1, 2021*

6.2. Analysis:

6.2.1. Introduction

Case Study	10th 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	Brownfield 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.  *Fig. (152) Site Land-use, Source: Google Earth, Edited by Author, Date accessed: 26 Feb. 2022*
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	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.  *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

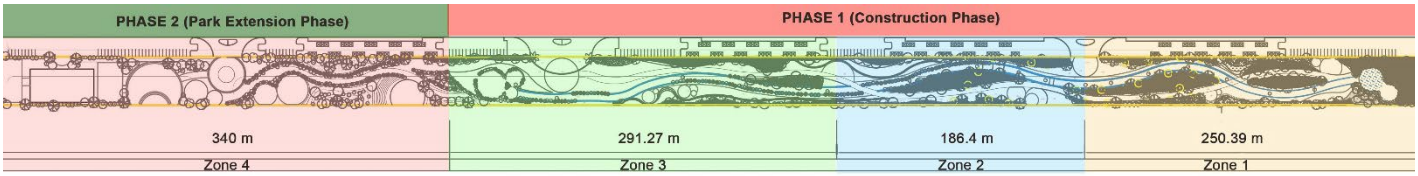
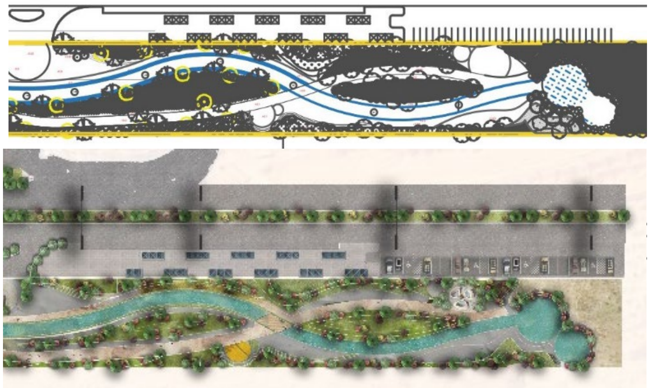
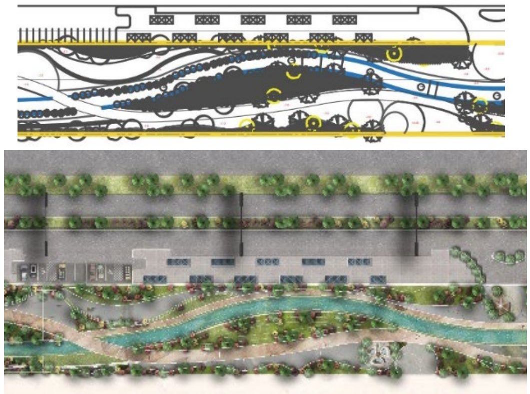
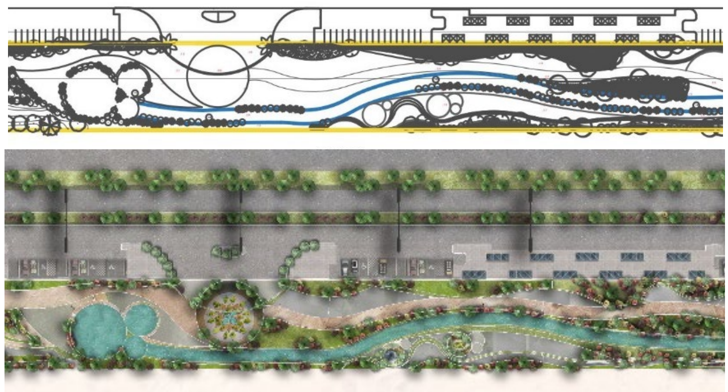
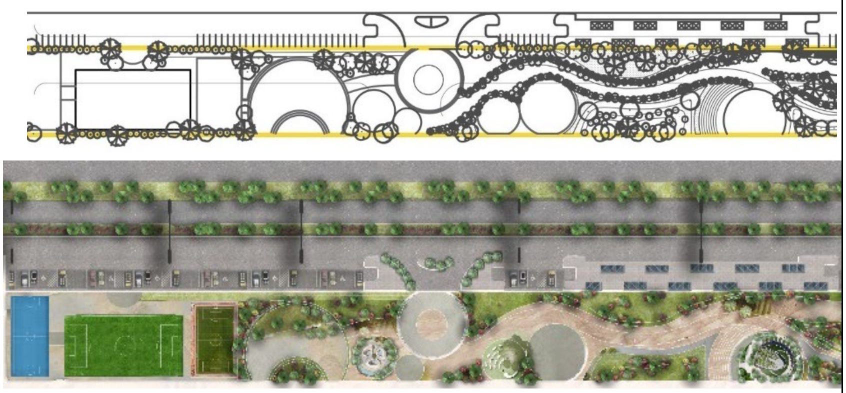


Table (25) Zone characteristics and Theme purposes, *Source: Author, Figures by Designers Academic team*

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 odurs 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:** Eleminate 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 repellant. 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.

<u>3D Model represented to stakeholders in a workshop on 6, 7 February 2021</u>,

Fig. (155): 3D Model for 10th Ramadan Wetland Park, Source: Designers Academic team

Project's Phases

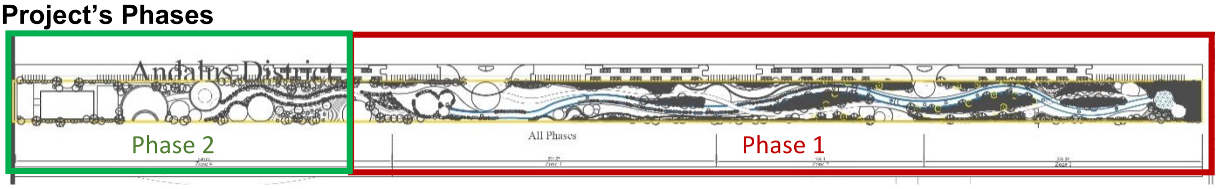
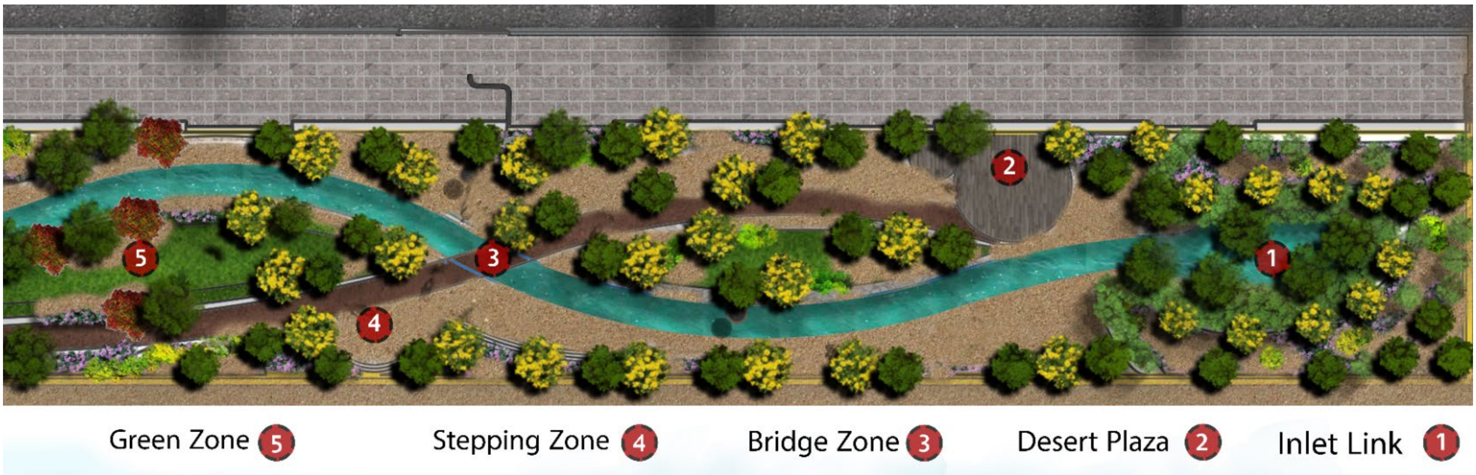
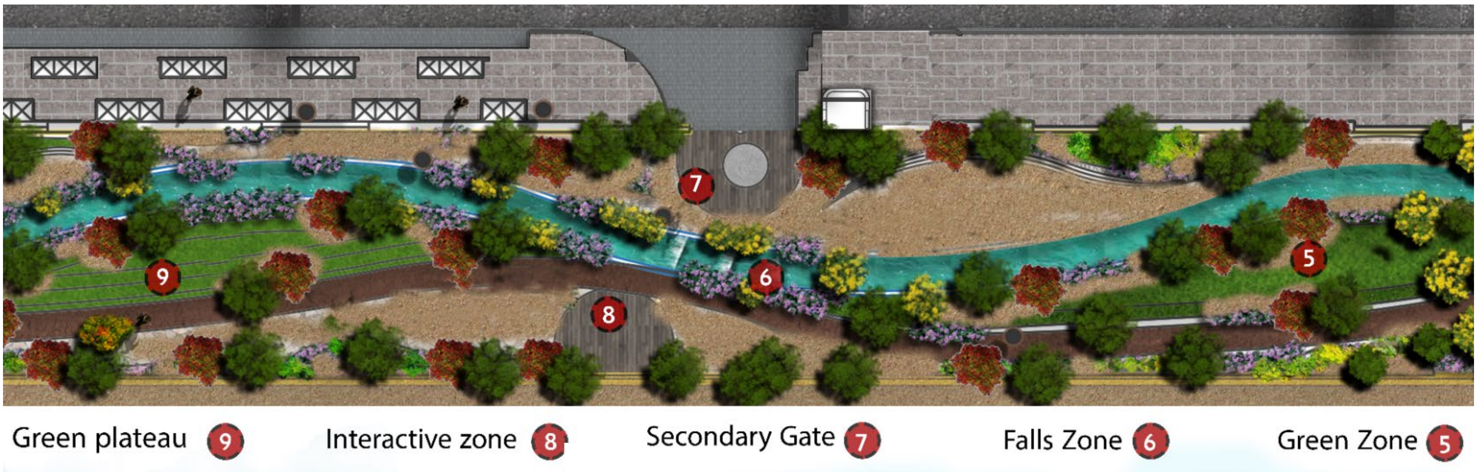


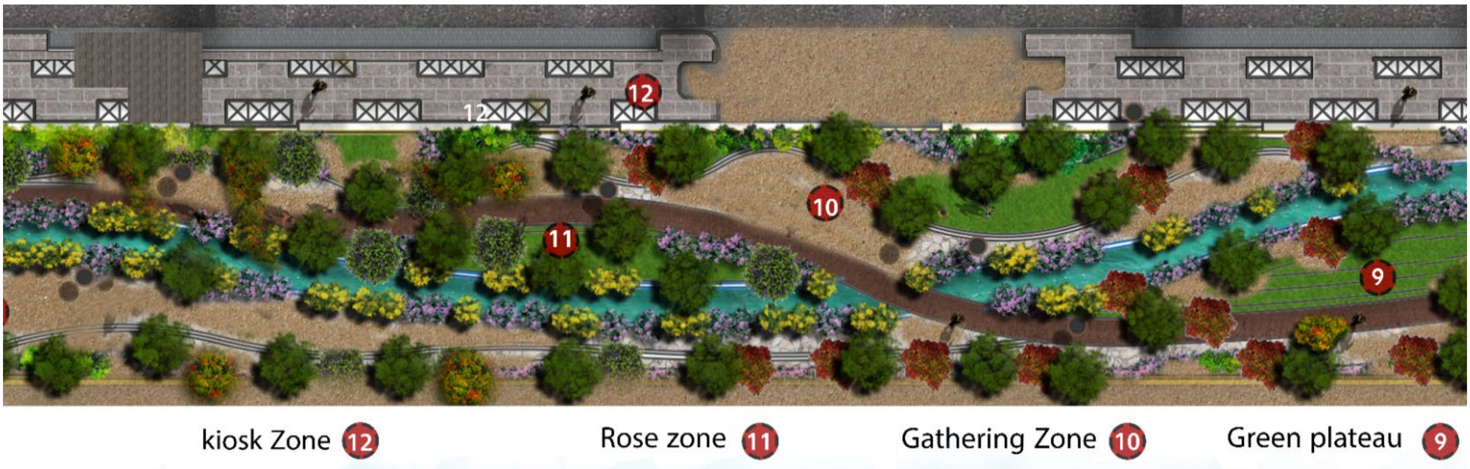
Fig. (156): Phases of the Wetland Park Project, Source: Designers Academic team, edited by Author

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.







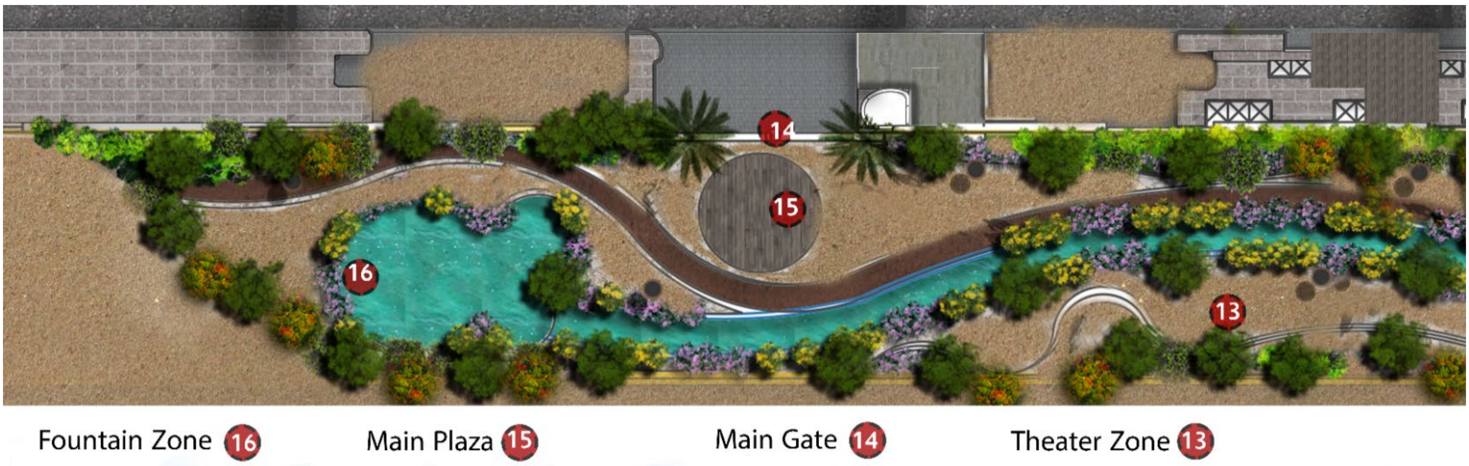


Fig. (157): Wetland Park Plan, Source: Designers Academic team

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.

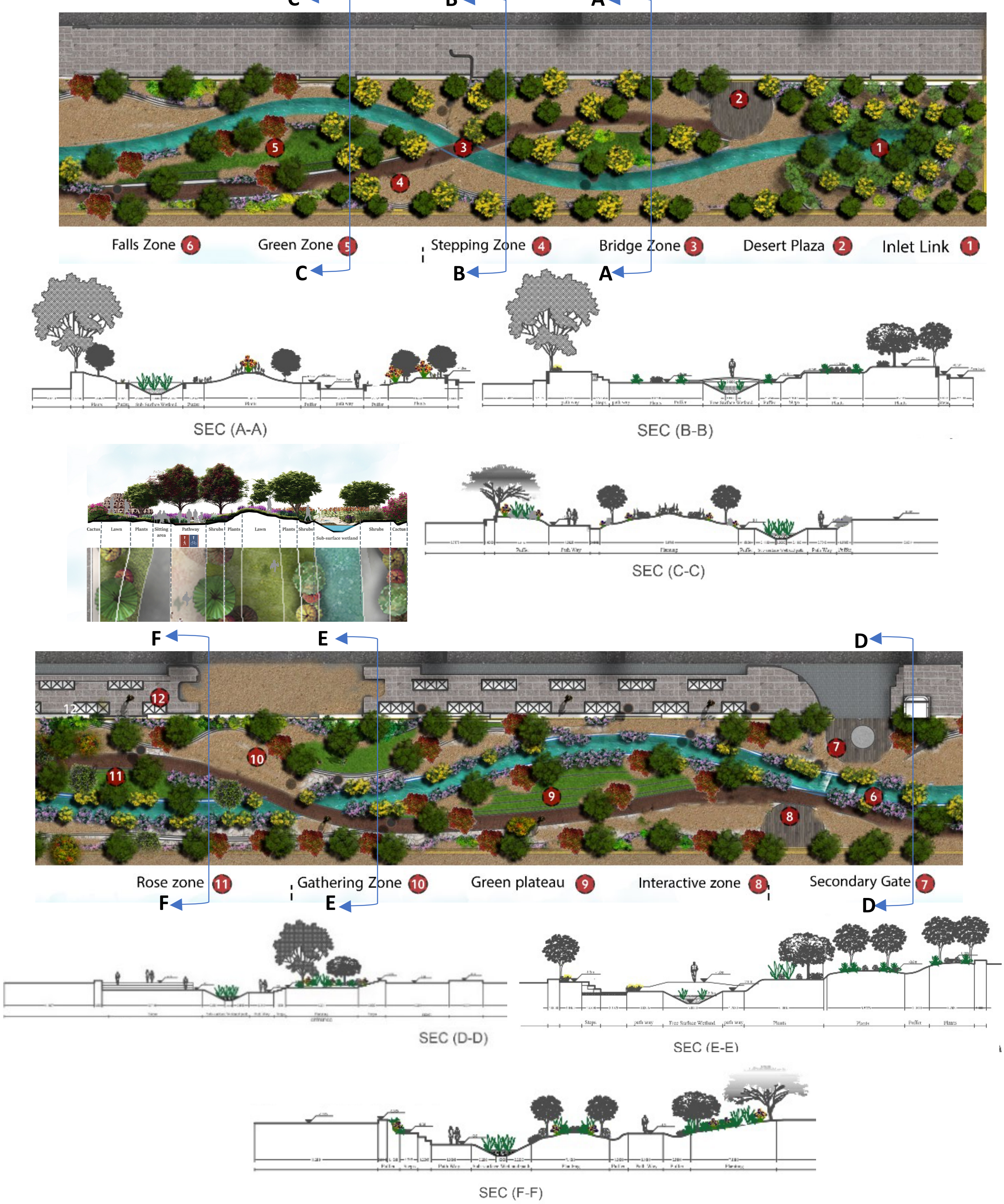


Fig. (158): Sections of the Wetland Park, Source: Designers Academic team, edited by Author

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	Bloom شهور التزهير												Form (Shape and Seasonal Changes) تكوين النبات ((الشكل والتغييرات 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										
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 البلح				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 نيلوتيكا، السنط، 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.	اللبخ، دقن 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	هجليج، بلح السكر، بلح 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 الجمل		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 ندوزا، العشرق						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	نارنج، 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 sinesnsis	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 المخيط						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.	بوانسيانا				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 المرجان				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	إرثرينا كفرا				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.	الجميز							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، هيما						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 اليسار، 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, 100-110 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 الشعور، الصفصاف الباكي			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. argyptiacia	السسبان، 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 هندى						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.	الطرفة							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.	النبق، 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	Bloom شهور التزهير												Form (Shape and Seasonal Changes) تكوين النبات ((الشكل والتغييرات 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										
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.	أجريتم				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.	أتريلكس					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.	سيزالبينيا					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	-
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 ayrantiacum 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	ياسمين زفر						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	ايفوربيا حمراء، بنت القنصل 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 القنصل	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 البرشومى					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	جلاديولس	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.	كركديه						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 سرياكوس، 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	بوستاشيا بيضاء					5	6	7						Evergreen	No Aroma	Fast	Moderate	Full Sun	Tolerant 800-1200 ppm	Tolerant	High	Medium living plant, 10 -12 years	-
22	Justicia spicigera	بوستاشيا برتقالى					5	6	7						Evergreen	Leaf	Fast	Moderate	Full Sun	Tolerant 800-1200 ppm	M. Tolerance	High	Medium living plant, 10 -12 years	-
23	Lantana camara	لانتانا 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.	حنة بلدى						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	بنتاس					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 مارى، حصا لبان					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.	فايتكس أخضر						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 شهور التزهير												Form (Shape and Seasonal Changes) تكوين النبات ((الشكل والتغييرات 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 أفرنجي	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	كليراء 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.	إيبوما خف الجمل							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 بلدى						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			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	ستيفانوتس							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	أشيلياء ألف زهرة			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	ألترنانتيرا 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				4	5	6							Evergreen	No Aroma	Fast	Moderate	Partial Shade / Full Sun	Intolerant	Intolerant	Non Resistant	Short living plant, 5-7 years	Recommended
4	Lantana camara nana	لانتانا 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	لانتانا 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	منثور		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	النرجس			3	4	5	6							Evergreen	Flower	Fast	Moderate	Partial Shade / Full Sun	Intolerant	Intolerant	Semi	Short living plant, 7-10 years	-
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 لبرء مدادة			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	شيح خرسانى			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	-
12	Tagetes erecta	القطيفة	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	زعتر جبلى							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	فربينا بلدى، فربينا 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 شهور التزهير												Form (Shape and Seasonal Changes) تكوين النبات ((الشكل والتغييرات 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	جوافة زهور						6	7	8					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						6	7	8	9				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، العُشر					5	6	7	8					Evergreen	Flower	Moderate	Low	Full Sun	Tolerant 800-1200 ppm	H. Tolerance	Semi	Medium living plant, 15-20 years	Check
4	Crassula hottentot	كراسولا السبحة					5	6	7						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			3	4	5								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 المسيح	1	2	3	4	5	6	7	8	9	10	11	12	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 الشوكى				4	5								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 شوكى أحمر				4	5								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	سيدم				4	5								Evergreen	No Aroma	Slow	Low	Partial Shade / Full Sun	Intolerant	Tolerant	High	Medium living plant, 25-30 years	H. Recommended
10	Yucca filamentosa	يوكا ابرية							7	8	9				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 كورتيديريا								8	9				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								8	9	10			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 الميكانثاس								8	9	10			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.	باسبالم سى شور، نجيل					5	6	7	8	9	10			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 odurs and Mosquito Repellant **Water:** Low - Minimum Water Requirement

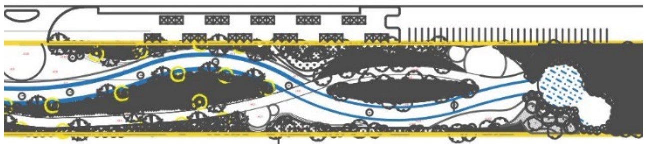


Table (30) Selected species for zone 1, Source: Author

Latin Name	Name in Arabic	Design Use and Value مجالات استخدام النبات في التصميم	Comments ملاحظات ايجابية أو سلبية Positive	 Negative	Selection	Reason of Selection
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 نيلوتيكا، 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
SHRUBS						
Cestrum ayrantiacum 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 Recommend	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 أفرنجي	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 Recommend	Everblooming Colorful hedge and barrier border
Groundcovers						
Thymus vulgaris	زعتر جبلي	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 Recommend	Moderate Water Requirements Effective security barriers
Mesembryanthemum cordifolia Syn. Aptenia, Litocarpus	أبتنيا	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 Recommend	Moderate Water Requirements Effective security barriers
Calotropis procera (Aiton) W.T.Aiton	العشار، العُشَر	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 Recommend	Low Water Requirements Effective security barriers
Opuntia ficus-indica Syn. O. engelmanni	التين الشوكي	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	تين شوكي 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	سيدم	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 Recommend	Low Water Requirements Effective security barriers
Yucca filamentosa	يوكا 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 Recommend	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 stay	Not used near walkways or play areas (sharp edges) Short living plant, 7-9 years	Check	Aromatic flower Effective security barriers

Zone 2

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:** Eleminate accessibility to zone 1 through buffer vegetation area **Shade:** Offer shading for users **Water:** Minimum Water Requirement

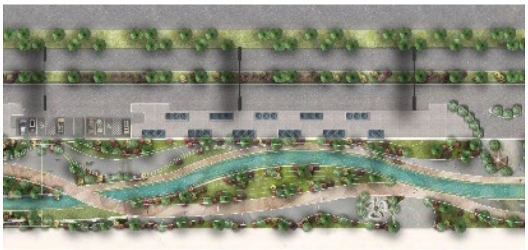


Table (31) Selected species for zone 2, Source: Author

Latin Name	Name in Arabic	Design Use and Value مجالات استخدام النبات في التصميم	Comments ملاحظات ايجابية أو سلبية: Positive	Comments: Negative	Selection	Reason of Selection
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 نيلوتيكا، 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
Albizia lebbeck (L.) Benth.	اللبخ، 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 Egypt7 Aromatic leaves Long Living plant, 40-50 years		H. Recommend	Offers shading for users Moderate Water Requirement
Erythrina caffra	إرثرينا 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 الباكي	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. Recommend	Offers shading for users Moderate Water Requirement
Sesbania sesban Syn. S. argyptiacia	السيسبان، 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.	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		High Recommend	Buffer to eliminate access to zone 1 Long flowering season Attractive Ornamental features Moderate Water requirements
Lawsonia inermis L.	حنة بلدى	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. Recommend	Buffer to eliminate access to zone 1 Attractive Aromatic Ornamental shrub Moderate Water requirements
Climbers						
Bougainvillea Stans	جهنمية أفرنجي	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	H. Recommend	Everblooming Colorful hedge and barrier border
Ipomoea pes-caprae (L.) R.Br.	إيبوما 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	Recommended	Ornamental climbing plant Away from user's contact
Solanum seaforthianum Andrews	سولانم، سيفورسيانم	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. Recommend	Ornamental plant Night-scented flowers Away from user's contact
Groundcovers						
Alternanthera species	ألترنانثيرا 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 com or 30 am 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	Recommended	Buffer to eliminate access 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 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	Recommended	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	Recommended	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

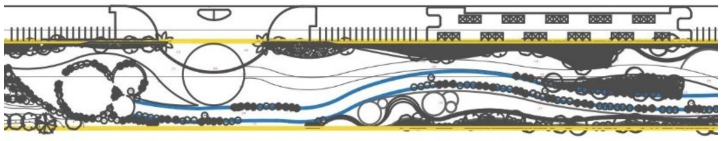


Table (32) Selected species for zone 3, Source: Author

Latin Name	Name in Arabic	Design Use and Value مجالات استخدام النبات في التصميم	Comments ايجابية أو سلبية ملاحظات — Positive	Negative	Selection	Reason of Selection
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 نيلوتيكا، 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، العشرق	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	بروسوبس، 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	جلاديولس	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 بلدى	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.	فايتكس أخضر	An ornamental specimen tree, planted along rivers and ponds Shrub border against walls Medicinal usage	Aromatic Flower Attractive floiage 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	Comments ايجابية أو سلبية ملاحظات Positive	Negative	Selection	Reason of Selection
Climbers						
Bougainvillea Stans	جهنمية أفرنجي	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	كليرا، 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 الدامى	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	Recommended	Ornamental beautful flower Cultivated foliage in public spaces Moderate Water requirements
Stephanotis floribunda	ستيفانوتس	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 beautful flower Strongly perfumed in public spaces
Groundcovers						
Achillea millefoliumm	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	ألترنانتيرا حمراء أو خضراء	Excellent for borders, beds, edging of large areas, as a house plant and in hanging baskets Grown for their multi-colored floiage Spaced 10 com or 30 am apart for carpet effect as groundcover	Grown for their multi-colored floiage Full sun and warm places allow for best leaf color	Flower only 2 months Frost intolerant	Recommended	Buffer to eleminate 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	Recommended	Buffer to eleminate accessibility to zone 1 Ornamental plant Away from user's contact
Portulaca grandiflora	رجلة صباح 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	فربينا بلدى، فربينا إنجليزى	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 كورتيديريا	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 الميكانثاس	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	Recommended	Ornamental at Park's entrance and public space Biodiversity Low water requirements
Paspalum vaginatum Sw.	باسبالم سى شور، نجيل	A groundcover for extended lawn areas and public spaces in gardens and parks Successful at coastal areas Control erossion in sandy areas	Blooming 6 months Paspalm 10, 8, 4 are commonly used in Egypt, Mow at 2-2.5 cm Control erossion 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

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

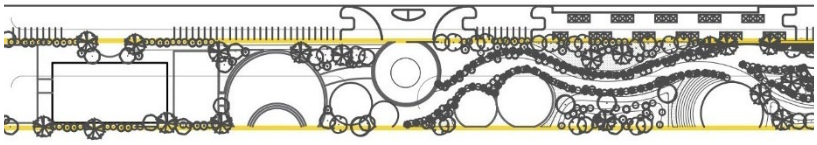


Table (34) Selected species for zone 4, Source: Author

Latin Name	Name in Arabic	Design Use and Value مجالات استخدام النبات في التصميم	Comments 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 نيلوتيكا، 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، العشرق	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 Medicinial 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 جراندیفلورا	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	ايفوربيا 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. Recommended	Long Flowering period
Lantana camara	لانتانا 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	Recommended	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 ماری، حصا لبان	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 فى التصميم	Comments ايجابية 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	لانتانا 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	لانتانا 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	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	Recommended	Attractive to different Fauna Species Aromatic Plant Vegetation is user-safe
Pelargonium peltatum	جارونيا ليرى 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	Bloom شهور التزهير												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	لانتانا 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	فربينا بلدى، فربينا 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	كليرا، 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	كرمة القلب الدامى		2	3	4									Recommended	3	Climbers
Solanum seaforthianum 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 millefoliumm	أشيليا، ألف زهرة			3	4	5								H. Recommended	3	Groundcovers
salix babylonica	صفصاف أم الشعور، الصفصاف 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	سيدم				4	5								H. Recommended	1	Succulents & Cacti
Phoenix dactylifera L.	نخيل البلح				4									Recommended	1-4	Palms
Paspalum vaginatum Sw.	باسبالم سى شور، نجيل					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.	سيزالبينيا					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	لانتانا كامارا					5	6	7	8					Recommended	4	Shrubs
Pentas lanceolata Syn. P. carnea	بنتاس					5	6	7	8					H. Recommended	3	Shrubs
Lantana montevidensis	لانتانا زرقاء					5	6	7	8					Recommended	4	Groundcovers
Calotropis procera (Aiton) W.T.Aiton	العشار، العُشر					5	6	7	8					Check	1	Succulents & Cacti
Sesbania sesban Syn. S. argyptiacia	السسبان، البان					5	6	7						Recommended	2	Trees
Crassula hottentot	كراسولا السبحة					5	6	7						Recommended	1	Succulents & Cacti
Hyphaene thebaica (L.) Mart.	نخيل الدوم					5	6							Check	1-4	Palms
Acacia nilotica	أكاسيا نيلوتيكا، السنط، شوكة مصرية					5	6							Recommended	1-4	Trees
Pongamia pinnata (L.) Pierre	بونجاميا					5	6							Check	4	Trees
Ziziphus spina-christi (L.) Desf.	النبق، السدر					5	6							Recommended	4	Trees
Salvia rosmarinus Spenn.	روز مارى، حصا لبان					5	6							Check	4	Shrubs
Cassia nodosa	كاسيا ندوزا، العشرق						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 ayrantiacum 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	بروسوبس، الغاف						6	7						Recommended	3	Trees
Hibiscus sabdariffa L.	كركديه						6	7						Check	4	Shrubs
Alternanthera species	ألترنانتيرا 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 ابرية							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	زعتر جبلى							7	8					Recommended	1	Groundcovers
Origanum vulgare Syn. Origanum majorana	بردقوش								8	9				Recommended	4	Groundcovers
Cortaderia selloana Asch. & Graebn.	حشيشة كورتيديريا								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	ايفوربيا 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 شهور التزهير												Selection	
1	Bougainvillea Stans	جهنمية أفرنجي	1	2	3	4	5	6	7	8	9	10	11	12	H. Recommended	Climbers
2	Euphorbia milii var. splendens	شوكة المسيح	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، العُشر					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 نيلوتيكا، السنط، شوكة مصرية، القرض					5	6							Recommended	Trees
8	Mesembryanthemum cordifolia Syn. Aptenia, Litocarpus	أبتنيا						6	7	8	9				H. Recommended	Succulents & Cacti
10	Cestrum ayrantiacum 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	جوافة زهور						6	7	8					H. Recommended	Succulents & Cacti
13	Yucca filamentosa	يوكا ابرية							7	8	9				H. Recommended	Succulents & Cacti
14	Thymus vulgaris	زعتر جبلي							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 شهور التزهير												Selection	
1	Bougainvillea Stans	جهنمية أفرنجي	1	2	3	4	5	6	7	8	9	10	11	12	H. Recommended	Climbers
2	Solanum seaforthianum Andrews	سولانم، سيفورسيانم			3	4	5	6	7	8	9				H. Recommended	Climbers
3	salix babylonica	صفصاف أم الشعور، الصفصاف الباكي			3	4									H. Recommended	Trees
4	Albizia lebbeck (L.) Benth.	اللبخ، دقن الباشا				4	5	6							Recommended	Trees
5	Anemone species	أنيمون				4	5	6							Recommended	Groundcovers
6	Erythrina caffra	إرثرينا كفرا				4	5								Recommended	Trees
7	Phoenix dactylifera L.	نخيل البلح				4									Recommended	Palms
8	Sesbania sesban Syn. S. argyptiacia	السيسبان، البان					5	6	7						Recommended	Trees
9	Hyphaene thebaica (L.) Mart.	نخيل الدوم					5	6							Check	Palms
10	Acacia nilotica	أكاسيا نيلوتيكا، السنط، شوكة 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 خضراء						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.	الطرفة							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 أفرنجي	1	2	3	4	5	6	7	8	9	10	11	12	H. Recommended	Climbers
2	Verbena hybrida	فربينا بلدى، فربينا 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	كليرا، طربوش 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 الدامى		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 البلح				4									Recommended	Palms
13	Paspalum vaginatum	باسبالم سى شور، نجيل					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	بنتاس					5	6	7	8					H. Recommended	Shrubs
16	Hyphaene thebaica (L.) Mart.	نخيل الدوم					5	6							Check	Palms
17	Acacia nilotica	أكاسيا نيلوتيكا، السنط، شوكة مصرية، القرض					5	6							Recommended	Trees
18	Cassia nodosa	كاسيا ندوزا، العشرق						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.	فايتكس أخضر						6	7	8					H. Recommended	Shrubs
22	prosopis juliflora	بروسوبس، الغاف						6	7						Recommended	Trees
23	Alternanthera species	ألترنانتيرا حمراء أو خضراء						6	7						Recommended	Groundcovers
24	Stephanotis floribunda	ستيفانوتس							7	8	9	10	11	12	H. Recommended	Climbers
25	Cortaderia selloana	حشيشة كورتيديريا								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 أفرنجي	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 البلح				4									Recommended	Palms
8	Barleria cristata	بارليريا					5	6	7	8					Recommended	Shrubs
9	Caesalpinia pulcherrima (L.) Sw.	سيزالبينيا					5	6	7	8					Recommended	Shrubs
10	Carissa grandiflora	كاريسا جرانديفلورا					5	6	7	8					Check	Shrubs
11	Hibiscus rosa-sinensis	هيبسكس 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 نيلوتيكا، 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.	روز مارى، حصا لبان					5	6							Check	Shrubs
19	Cassia nodosa	كاسيا ندوزا، العشرق						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.	كركديه						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	ايفوربيا 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

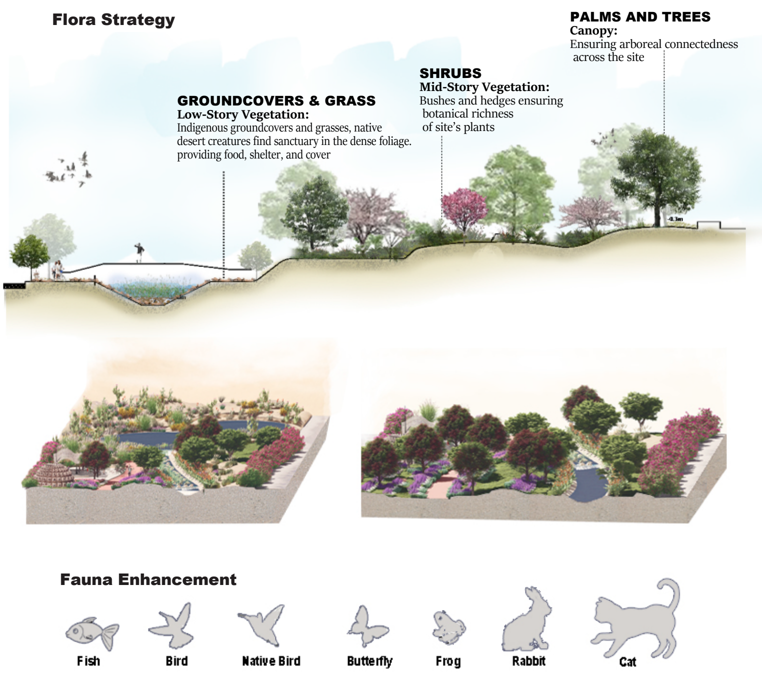
- Project studies related to water, soil and air quality
- Online calculators and tools; iTree Eco

Secondary Data

- Publications and research studies
- Workshop with Stakeholders

Primary Data

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



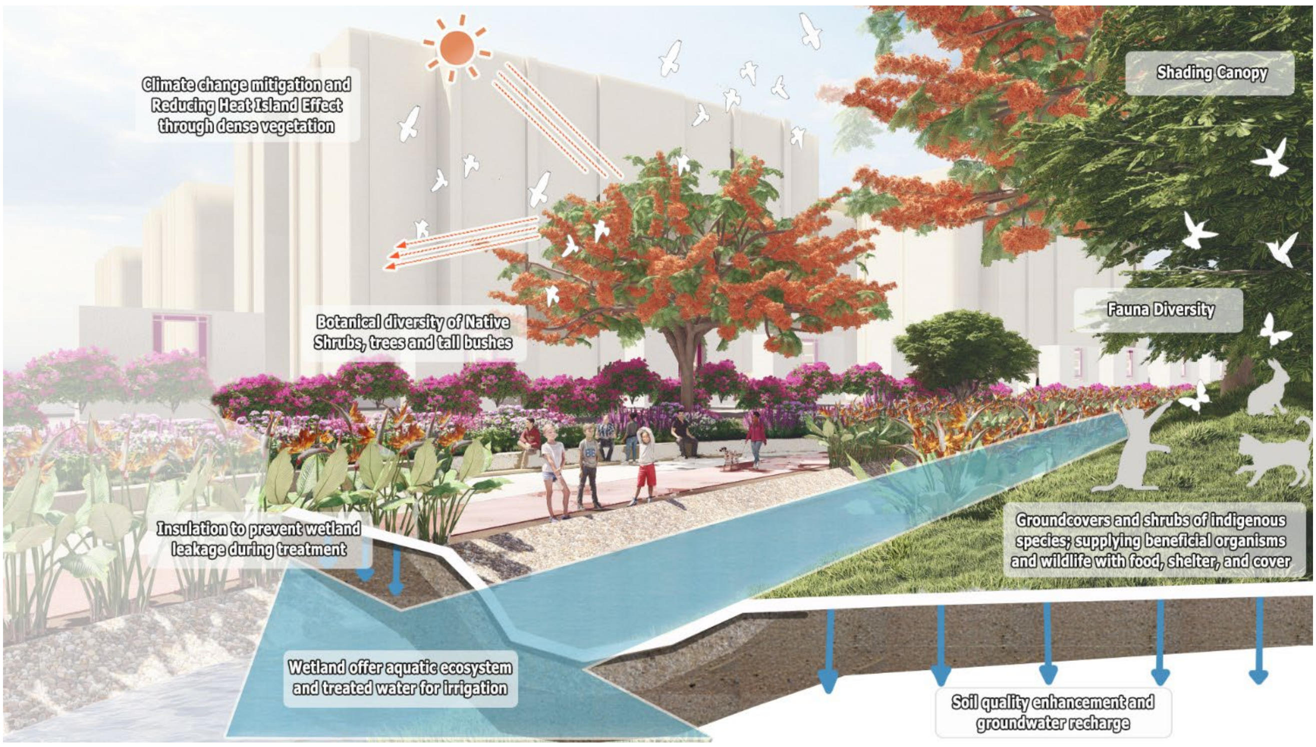


Fig. (159) Expected 10th of Ramadan Wetland Park's performance, Source: Author *on rendered shots by Designers Academic team*

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

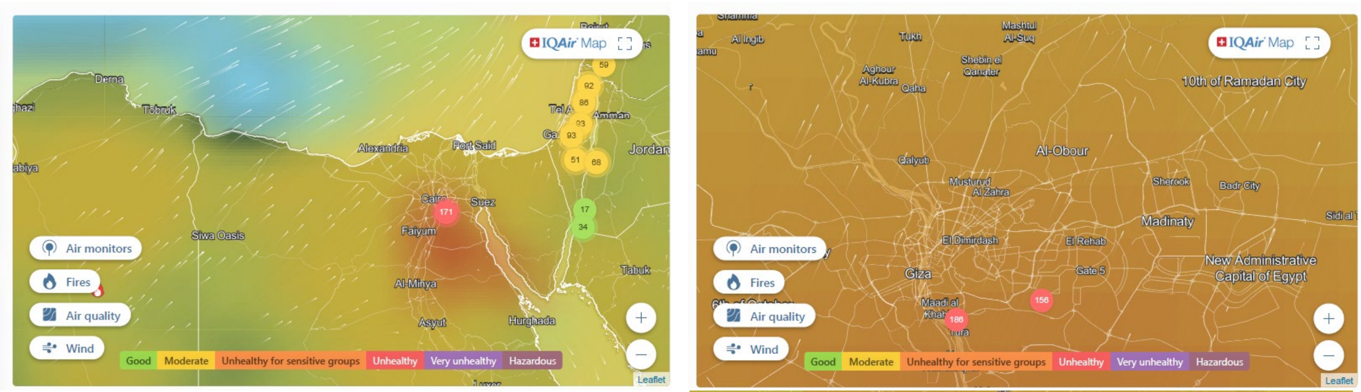
Table (42) Air Quality Index (AQI) and pollutants' values, EPA's breakpoint, Source: Saad, S., et al., 2017 and Great Merce, TMA, 2022

Hourly AQI index

Air checker hourly AQI			$PM_{2.5}$ Hourly µg/m³	PM_{10} Hourly µg/m³	NO_2 Hourly µg/m³	O_3 Hourly µg/m³
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	4560	45-60	60-80
	Insufficient	41-50	40-50	60-75	60-75	80-100
Bad	Rather poor	31-40	50-70	75100	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: Aircheckr, 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 PM2.5 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

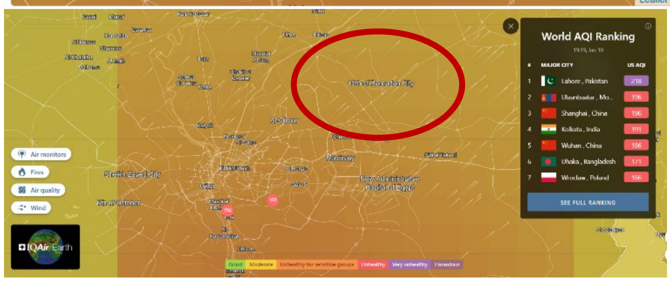


Fig. (160) Daily Air Quality Index (AQI) at site location, Source: IQ Air, 2022, on 10 January 2022

Measurement Date	Air pollution level	Air quality index	Main pollutant
10 January 2022, at 13:00	Unhealthy	156 US AQI	PM2.5; Concentration 65.5 µg/m³
19 January 2022, at 13:50	Unhealthy	172 US AQI	PM2.5; Concentration 95.7 µg/m³

Table (44) Site's Air Quality Index, Source: IQ Air, 2022, on 10 & 19 January 2022

! PM2.5 x13.1 **PM2.5 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.

! PM2.5 x19.1 **PM2.5 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/m3 annual mean 15 µg/m3 24-hour mean **Coarse particulate matter (PM10)** 15 µg/m3 annual mean 45 µg/m3 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.
Ozone (O_3)	100 µg/m3, 8-hour daily maximum* 60 µg/m3 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 O3 concentration in the six consecutive months with the highest six-month running average O3 concentration
Nitrogen dioxide (NO2)	10 µg/m^3 annual mean 25 µg/m^3 24-hour mean	The current WHO guideline value of 10 µg/m3 (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 SO2 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/m³
PM_{10}	40	55	57	ug/m³

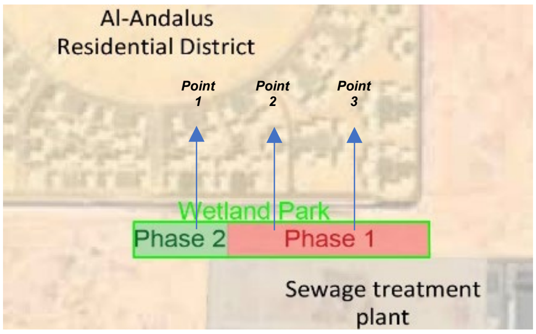


Fig. (161) Weather condition during Air Quality Measure's visit, Source: Author, Date Taken: 19 February 2022 at 10:53

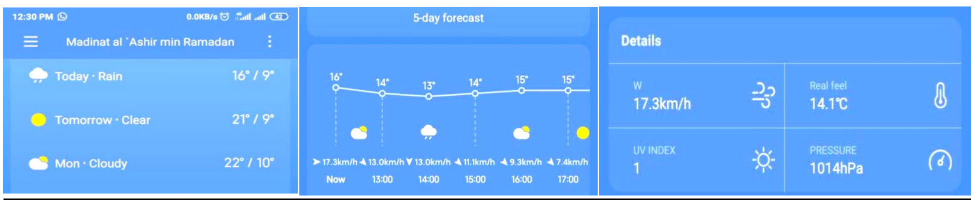


Fig. (162) Measuring and analysis of site's Air Quality, Source: Author, Date Taken: 19 February 2022 from 10:30 to 13:00

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
Ai	Trees	Azadirachta	indica	25.3	517	69.5	10.8	3.8	0.04	0.05	0	0	-0.01
Cag	Trees	Cassia	glauca	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	grandilflora	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	angustifola	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
  - $1.63 per kilogram (CO),
  - $0.11 per kilogram (O3),
  - $0.01 per kilogram (NO2),
  - $0.00 per kilogram (SO2),
  - $-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:

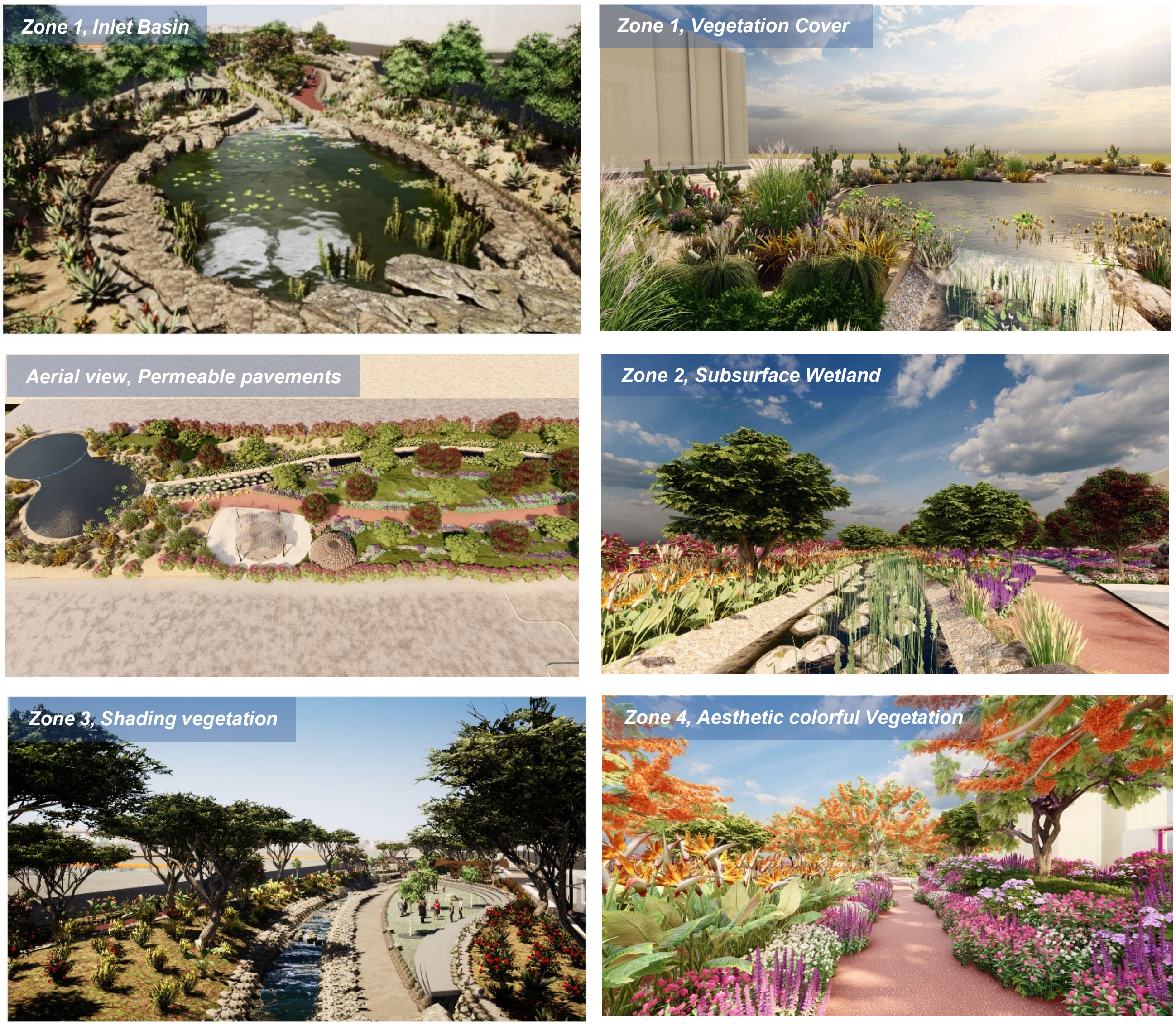
According to researchers at Lawrence Berkeley National Laboratory (LBNL), Studies estimated the following (Pomerantz, M., et al., 2000; Taha, H., 1996; Taha, H., 1997):

- Decrease of surface temperature by **4ºC** for every 10 % increase in solar reflectance
- Reduction in air temperature by **0.6ºC** 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 (CO_2) 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
Ai	Trees	Azadirachta	indica	1216	41.1	1.5	1.3
Cag	Trees	Cassia	glauca	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	grandilflora	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	angustifola	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 int 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.

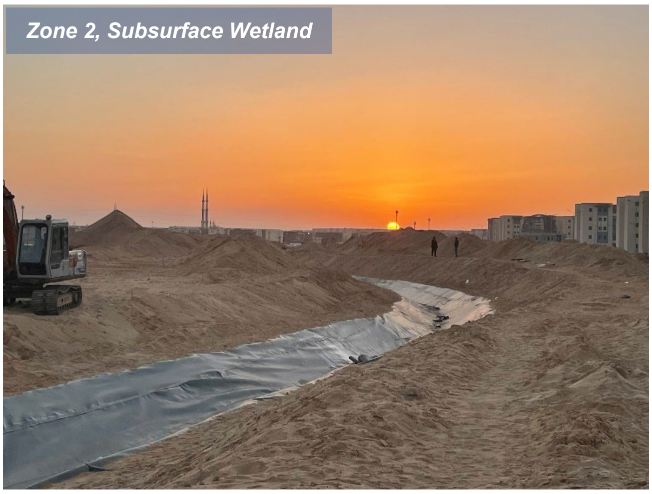


Fig. (164): Insulation of the water pathway at Park, Source: Author, Date Taken: November 27, 2021, at 16:40

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	Cassia nodosa	كاسيا نودوزا	Semi deciduous tree	60-80	Pink in summer and autumn
2	*Peltophorum africanum*	بلتوفورم	Evergreen tree	60-80	yellow in summer and autumn
3	*Ailanthus altissima*	شجرة السماء	Deciduous tree	40-50	greenish-white in spring
4	*Ceratonia Siligua*	الخروب	Evergreen tree	40-50	red or tend to red in autumn
5	*Acacia farnesiana*	الفتنة	Deciduous tree	40-50	Orange-yellow in spring (fragrant smell)
6	*Koelreuteria panniculata*	كولروتيريا	Evergreen tree	50-60	Blossoms are yellow in (autumn) they turn red
7	*Citharexylum quadrangular*	السندروس	Deciduous tree	50-60	Vegetable trees (worthless flowers)
8	*Spathodea campanulata*	اسبائوديا	Evergreen tree	60-80	Red in winter
9	*Khaya senegalensis*	الكايا- الماهوجني الأفريقي	Deciduous tree	60-80	Yellow flowers in summer
10	*Bauhinia sp*	خف الجمل	Deciduous tree	50-60	Pink, white, and purple flowers in spring
11	*Bombax malabaricum*	البومباكس	Deciduous tree	60-80	Red in winter and spring
12	*Delonix regia*	البوانسيانا	Deciduous tree	60-80	Red in summer
13	*Erthrina variegata*	إرثرينا	Deciduous tree	60-80	Red in winter and spring
14	*Ficus laurifolia*	فيكس مانجو	Evergreen tree	60-80	Vegetable trees (worthless flowers)
15	*Morus sp*	التوت	Deciduous tree	50-60	Vegetable trees (worthless flowers)
16	*Tecoma stans*	التيكوما الصفراء	Evergreen tree	50-60	Yellow in spring, summer, and fall
17	*Thevitea peruviana*	ثيفيتيا	Evergreen tree	50-60	Yellow- orange in summer, and fall
18	*Paulownia tomentosa*	بولونيا	Deciduous tree	60-80	White in winter and spring
19	*Pongamia pinnata*	بونجاميا	Deciduous tree	50-60	Reddish white in spring
20	*Moringa oleifera*	المورينجا	Deciduous tree	50-60	White - creamy in May with an aromatic scent
21	*Albizia julibrissin*	كاليترا	Deciduous tree	35-40	Pink in spring and summer
22	*Pittosporum tobira*	البتسبورم	Evergreen shrub	25-30	White/yellow aromatic scent flowers in winter/spring
23	*Murraya paniculata*	موريا	Evergreen shrub	25-30	White or cream in spring, aromatic
24	*Plumeria alba*	الياسمين الهندى	Deciduous shrub	30-40	Yellowish white in summer
25	*Ervatamia coronaria*	تابرنا	Evergreen shrub	25-30	White blossoms in spring, summer / autumn - aromatic
26	*Acalypha wilkesiana*	أكاليفا	Evergreen shrub	25-30	used for leaf beauty (valueless flowers)
27	*Hibiscus rosa-sinensis*	هبسكس	Evergreen shrub	25-30	Red almost the whole year
28	*Lagerstroemia indica*	تمر حنة	Evergreen shrub	25-30	Pink, red or white in summer
29	*Tecomaria capensis*	تيكوماريا حمراء	Evergreen shrub	25-30	Red all year long
30	*Russelia equisetiformis*	روسيليا	Evergreen shrub	25-30	Red in winter and spring
31	*integerrimaJatropha*	جاتروفا	Evergreen shrub	25-30	Flowers in red clusters almost all year long
31	*Leucophyllum frutescens*	ليكوفيلم	Evergreen shrub	25-30	Violet/ purple/ pink. June through late summer / early fall
32	*Phoenix dactylifara*	نخيل البلح	Palm tree	60-80	-----
33	*Washingtonia sp*	برتشارديا	Ornamental tree	60-80	----
34	*Plumbago auriculata*	البلمباجو	Climber/Evergreen shrub	25-30	Sky blue flowers in clusters almost all year long
35	*Clerodendron splendens*	كليرا	Evergreen Climber	25-30	Red flowers in clusters in winter and spring
36	*Ipomea palmata*	ست الحسن	Evergreen Climber	15-20	Bell's flowers are purple almost all year long
37	*Thenbergia grandiflora*	ثمبرجيا	Evergreen Climber	15-20	Cyan blossoms all year long
38	*Crinum asiaticum*	كرينم ابيض	Summer bulbs	5-15 liter/ m2/ day	Big white trumpet flowers scented in summer
39	*Hemerocallis aurantica*	الهيميروكالس	Summer bulbs	5-15 liter/ m2/ day	Orange blossoms in summer and autumn
40	*Canna indica*	الكانا (السنبل)	Summer bulbs	5-15 liter/ m2/ day	Flowers of different colors throughout the year
41	*Aptenia cordifolia*	ابتينيا زاحف	Ground cover	5-15 liter/ m2/ day	Flowers are red in spring, summer, and fall
42	*Portulacaria grandiflora*	رجلة الزهور	Ground cover	5-15 liter/ m2/ day	many colors flowers
43	*Lantana montevidensis*	لانتانا مدادة	Ground cover	5-15 liter/ m2/ day	Blue blossoms in summer
44	*Duranta erecta"Gold Mound*	دورانتا ليموني	Edging plants	5-15 liter/ m2/ day	Blue flowers in spring and summer
45	*Rosemarinus officinalis*	حصى لبان	Edging plants	5-15 liter/ m2/ day	lusters of pale blue to white flowers in winter and spring
46	*Senecio cineraria*	زنراريا	Ground cover	5-15 liter/ m2/ day	Yellow flowers
47	*Sansevieria hyacinthoides*	جلد النمر الأخضر	Succulent plant	5-15 liter/ m2/ day	---------------
48	*Sansevieria trifasciata*	جلد النمر الأصفر	Succulent plant	5-15 liter/ m2/ day	---------------
49	*Yucca filamentosa*	يوكا ابره ادم	Succulent plant	5-15 liter/ m2/ day	---------------
50	*Peniocereus striatus*	الشمعدان	Succulent plant	5-15 liter/ m2/ day	---------------
51	*Euphorbia tirucalli*	اللبنية	Succulent plant	5-15 liter/ m2/ day	---------------
52	*Euphorbia splendens*	إيفوربيا دم المسيح	Succulent plant	5-15 liter/ m2/ day	---------------
53	*Euphorbia nerifolia*	إيفوربيا الجوافة	Succulent plant	5-15 liter/ m2/ day	---------------
54	*Alpinia nutans*	ألبينيا	semi aquatic plant	5-10	---------------
55	*Pennisetum sp*	بنسيتم	aquatic plant	5-15	---------------
56	*Paspalum vaginatum*	بسبالم	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 إحتياج للمياه	Sun شمس	Salinity تحمل الملوحة	Drought تحمل الجفاف	Wind تحمل الرياح	Quan-tity
			1	2	3	4	5	6	7	8	9	10	11	12										
PALMS																								
Phoenix dactylifera	نخيل البلح	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	اسباثوديا	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 / ليموني	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	ونكا	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	لانتانا 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 لبر، 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	باسبالم سى شور، نجيل	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	لانتانا صفراء	1	2	3	4	5	6	7	8	9	10	11	12	Bright Yellow	Groundcovers
Phoenix dactylifera	نخيل البلح				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	باسبالم 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	اسباثوديا						6	7			10	11		Yellow-rimmed - Scarlet-red	Trees
Cordyline fruticosa	كورديلن							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	Carbon Storage of Individual Trees		Carbon Sequestration of Individual Trees		Avoided Runoff		Pollution Removal		Total Annual Benefits
					(cm)	($)	(kg/yr)	(kg)	($)	(kg/yr)	($/yr)	(m³/yr)	($/yr)	(g/yr)	($/yr)	($/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
Ai	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	glauca	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	angustifola	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
  - $1.63 per kilogram (CO),
  - $0.11 per kilogram (O3),
  - $0.01 per kilogram (NO2),
  - $0.00 per kilogram (SO2),
  - $-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											
				Import-ance 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	grandilflora	**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	roundcovers	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	**48**	2	3.7	2	0.4	2.3	0.1	1.1	0.3	0.2	<0.1	<0.1
Lo	Shrubs	Lavandula	angustifola	**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	grandilflora	**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	angustifola	**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 (g/yr)	Monoterpene (g/yr)	VOCs (g/yr)
Pd	Palms	Phoenix	dactylifera	142.8	0	142.8
Ai	Trees	Azadirachta	indica	6.4	27.1	33.5
Cag	Trees	Cassia	glauca	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	grandilflora	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	angustifola	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
Ai	Trees	Azadirachta	indica	4.01	1.5	400	35	140.35	52.5	14000
Cag	Trees	Cassia	glauca	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	grandilflora	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	angustifola	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 5orders 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 m^3)
- 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	grandilflora	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	angustifola	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 $2.361/$m^3$. 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	**NH_3**	mg/l	10.50	1.7	1.8
Major Cations					
Calcium	**Ca**	mg/l	71.05	66.24	64.32
Potasium	**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	**NO_2**	mg/l	<0.2	0.24	0.20
Nitrate	**NO_3**	mg/l	0.48	0.96	0.96
Sulfate	**SO_4**	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 m^3/sec

2- **Meteorological Data:** Temperature = 30 ^{0}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 m^3/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.

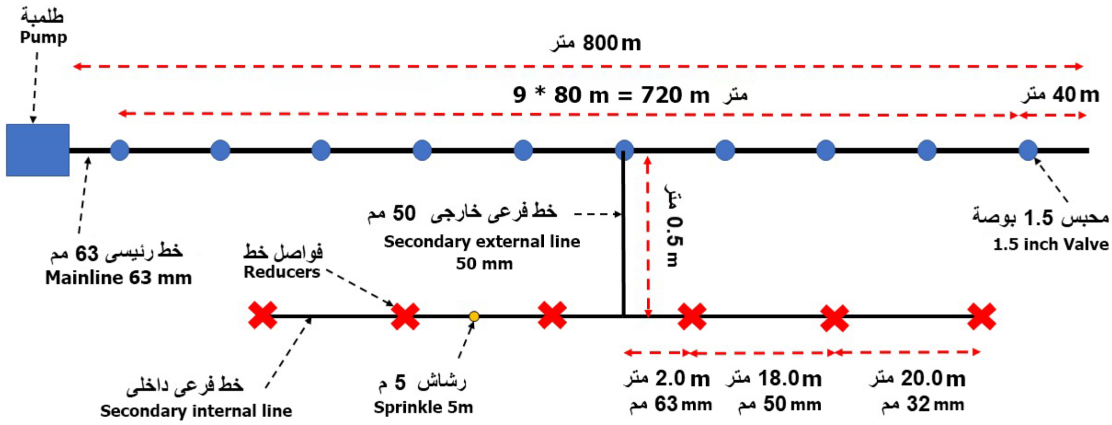


Fig. (165) Irrigation concept for treated water reuse,
Source: Edited by Author from Mechanical team, Designers Academic team's 2nd report

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 w hile 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

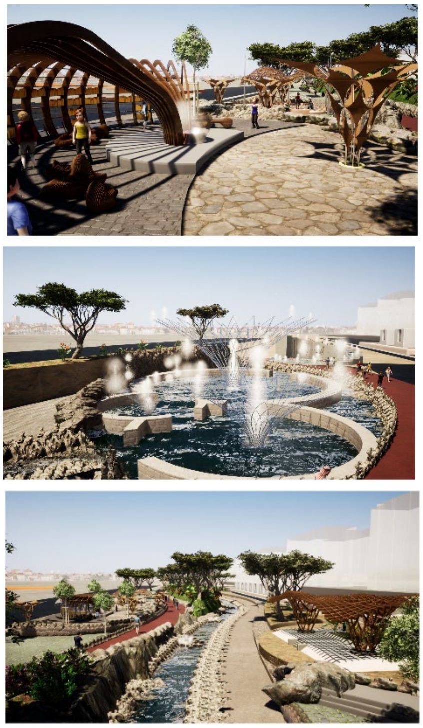


Fig. (168) Recreational Areas renderings, Source: Design Academic team

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.

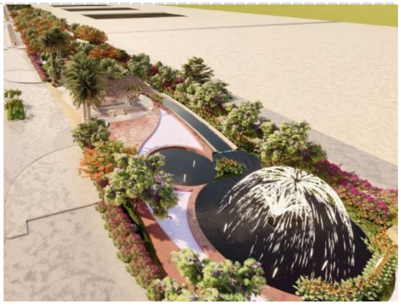


Fig. (173) Water features renderings, Source: Design Academic team

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
Socio/ Economic Benefits	<u>SOCIAL</u> • 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 <u>ECONOMY</u> • 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

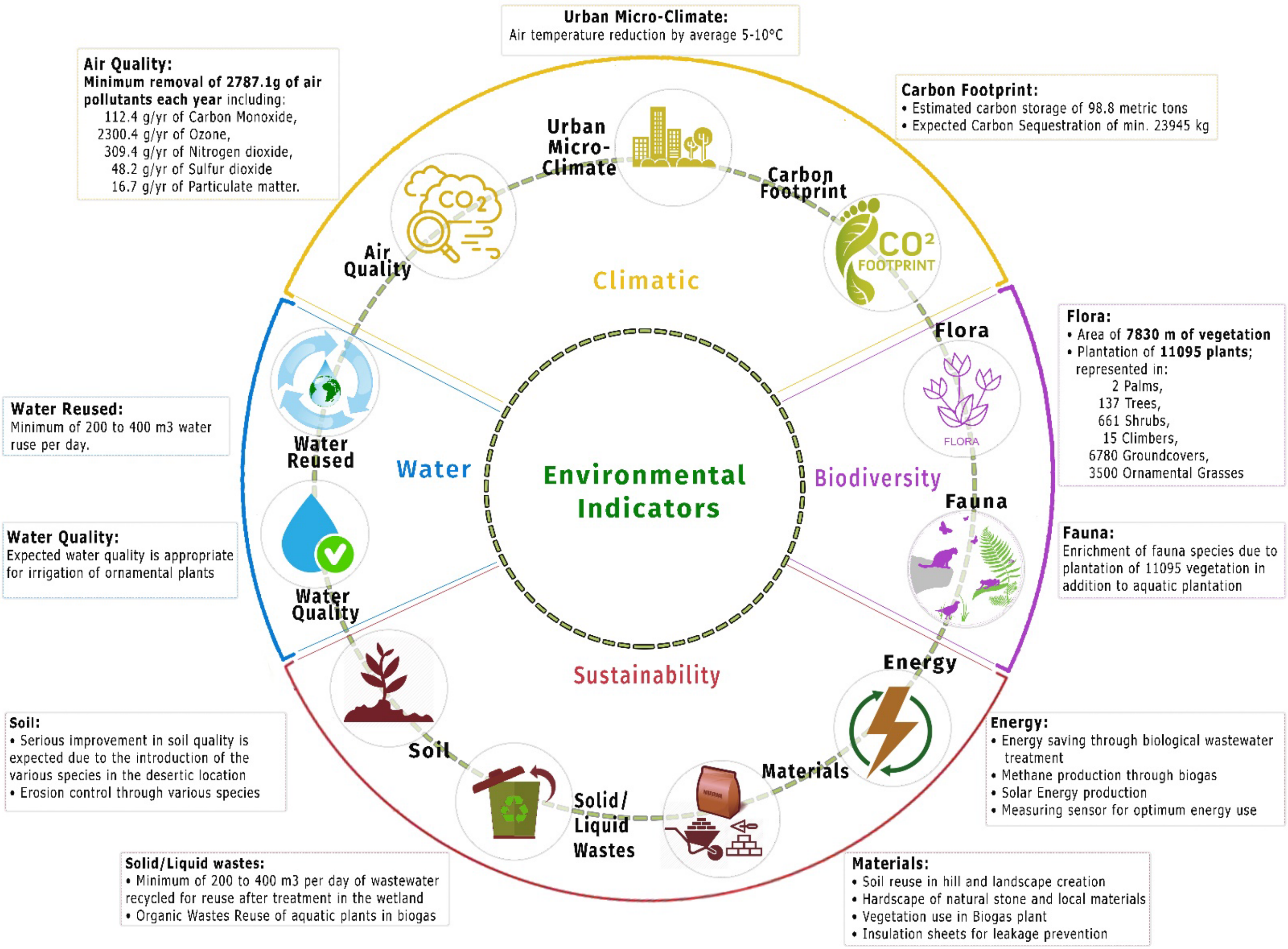
6.6. Case study's Environmental Analysis Summary

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	• 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.
		Urban Micro-Climate	- **Heat Island Effect:** % of decrease in Heat Island Effect due to increased vegetation cover and water bodies	Quantitative	• Air temperature reduction by average 5-10°C
		Carbon Footprint	- **Carbon Footprint:** amount of carbon dioxide and other GHG emissions associated with the wetland project compared to conventional treatment plant	Quantitative	• Estimated carbon storage of 98.8 metric tons • Carbon Sequestration minimum of **23945 kg** is expected
	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	• 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	• 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	• 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 m^3 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	• 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	• 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	• 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	• Minimum of 200 to 400 m^3 water ruse per day.
		Water Quality	- **Water quality:** % of pathogens removed through the constructed wetland	Quantitative	• 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:	10th Ramadan Wetland
Project Type:	Constructed Wetland Park
Location:	10th City, Cairo Governerate, Egypt, 30°20'17.9"N 31°47'19.2"E
Climatic Zone:	Arid Climate, BWh
Hardiness Zone:	10
Assessment Author:	Aya ElMeligy

Impacts / Activities			Project Activities																	
			Construction Phase									Operation Phase								
Category		Impact Factors (IF)	Construction Phase Assessment (top)	(left)	(right)	(bottom)	IV= Impact Value relevance S*M*P*D	EIV= $\sum_{i=1} Mi*Si*Pi*Di$ Impact Factor Ratio R= IV/EIV	Weight Based on Questionnaire	IV Weight Relevance (IVWR)	Percentage Achieved	Operation Phase Assessment (top)	(left)	(right)	(bottom)	IV= Impact Value relevance S*M*P*D	EIV= $\sum_{i=1} Mi*Si*Pi*Di$ Impact Factor Ratio R= IV/EIV	Weight Based on Questionnaire	IV Weight Relevance (IVWR)	Percentage Achieved
Environmental Impact Factors	Climatic Aspects	Air Quality	2	5	2	5	100	0.048520136	0.8	0.0388161	40.00%	5	5	2	5	250	0.050060072	0.9	0.0450541	100.00%
		Urban Micro-Climate	2	4	2	2	32	0.015526443	0.7	0.0108685	12.80%	5	5	2	5	250	0.050060072	0.9	0.0450541	100.00%
		Carbon Foot-print	1	3	2	2	12	0.005822416	0.7	0.0040757	4.80%	3	4	2	3	72	0.014417301	0.8	0.0115338	28.80%
		Noise	0	0	1	3	0	0	0.7	0	0.00%	3	2	2	1	12	0.002402883	0.8	0.0019223	4.80%
	Sustainability	Energy	5	5	2	5	250	0.12130034	0.7	0.0849102	100.00%	5	5	2	5	250	0.050060072	0.8	0.0400481	100.00%
		Materials	5	5	2	5	250	0.12130034	0.8	0.0970403	100.00%	5	5	2	5	250	0.050060072	0.8	0.0400481	100.00%
		Solid/ Liquid Wastes	3	5	2	5	150	0.072780204	0.8	0.0582242	60.00%	5	5	2	5	250	0.050060072	0.8	0.0400481	100.00%
		Soil	2	4	1	2	16	0.007763222	0.8	0.0062106	6.40%	3	5	2	4	120	0.024028835	0.8	0.0192231	48.00%
	Biodiversity	Flora (Vegetation)	3	5	2	5	150	0.072780204	0.9	0.0655022	60.00%	5	5	2	5	250	0.050060072	0.9	0.0450541	100.00%
		Fauna	2	4	2	4	64	0.031052887	0.8	0.0248423	25.60%	4	5	2	5	200	0.040048058	0.8	0.0320384	80.00%
	Water	Water Reused	0	5	1	3	0	0	0.9	0	0.00%	5	5	2	5	250	0.050060072	0.9	0.0450541	100.00%
		Water Quality	0	5	1	3	0	0	0.9	0	0.00%	4	5	2	5	200	0.040048058	0.9	0.0360433	80.00%
Socio-Cultural Impact Factors	Community Values	Community Size Served	1	2	1	2	4	0.001940805	0.8	0.0015526	1.60%	3	5	2	3	90	0.018021626	0.8	0.0144173	36.00%
		Community Awareness	2	3	1	4	24	0.011644833	0.8	0.0093159	9.60%	3	4	2	4	96	0.019223068	0.8	0.0153785	38.40%
		Community Acceptance	3	4	2	3	72	0.034934498	0.8	0.0279476	28.80%	4	4	2	4	128	0.025630757	0.8	0.0205046	51.20%
	Social Values	Education / Training	3	3	1	5	45	0.021834061	0.8	0.0174672	18.00%	4	4	2	5	160	0.032038446	0.8	0.0256308	64.00%
		Public Participation	2	2	1	4	16	0.007763222	0.8	0.0062106	6.40%	3	4	2	4	96	0.019223068	0.8	0.0153785	38.40%
		Increased Recreational & Social Activities	1	1	1	4	4	0.001940805	0.9	0.0017467	1.60%	5	5	2	5	250	0.050060072	0.9	0.0450541	100.00%
		Added Social, Connectivity & Safety Values	1	1	1	4	4	0.001940805	0.8	0.0015526	1.60%	5	5	2	5	250	0.050060072	0.8	0.0400481	100.00%
	Aesthetic Values	Visual Aesthetic Value	1	1	1	4	4	0.001940805	0.9	0.0017467	1.60%	5	5	2	5	250	0.050060072	0.9	0.0450541	100.00%
		Odor Reduction Efficiency	0	0	1	2	0	0	0.8	0	0.00%	3	5	2	5	150	0.030036043	0.8	0.0240288	60.00%
Economical -Technical Impact Factors	Economic Values	Catalyzing Economic Development	2	4	1	3	24	0.011644833	0.8	0.0093159	9.60%	3	4	2	5	120	0.024028835	0.8	0.0192231	48.00%
		Land Use Value	3	5	2	3	90	0.043668122	0.8	0.0349345	36.00%	3	5	2	5	150	0.030036043	0.8	0.0240288	60.00%
		Economic Savings	5	5	2	5	250	0.12130034	0.8	0.0970403	100.00%	5	5	2	5	250	0.050060072	0.8	0.0400481	100.00%
		Potentials of Economic Revenue	0	5	2	2	0	0	0.8	0	0.00%	3	5	2	5	150	0.030036043	0.8	0.0240288	60.00%
	Technical Values	Construction Process Flexibility	5	5	2	5	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	5	2	5	250	0.050060072	0.8	0.0400481	100.00%
		Future Potential for Upgrading	5	5	2	5	250	0.12130034	0.9	0.1091703	100.00%	5	5	2	5	250	0.050060072	0.9	0.0450541	100.00%

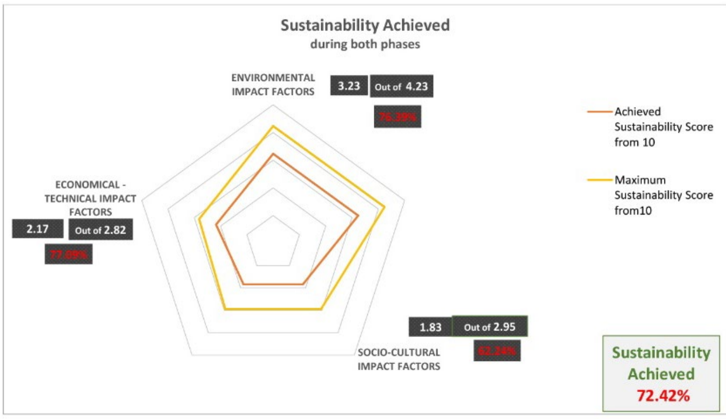
6.7.1. Sustainability Analysis and Representative Charts

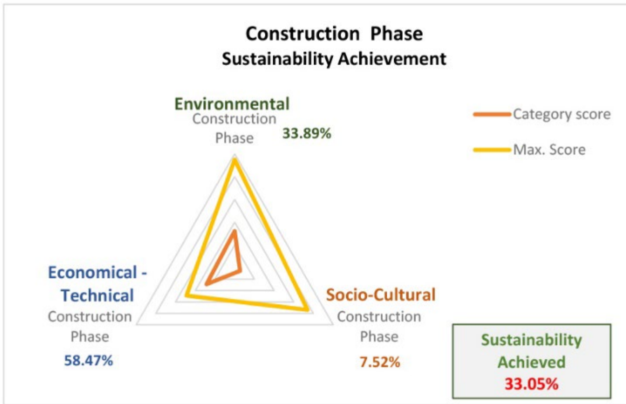
Fig. (179) Wetland Park's sustainability analysis, Source: Author

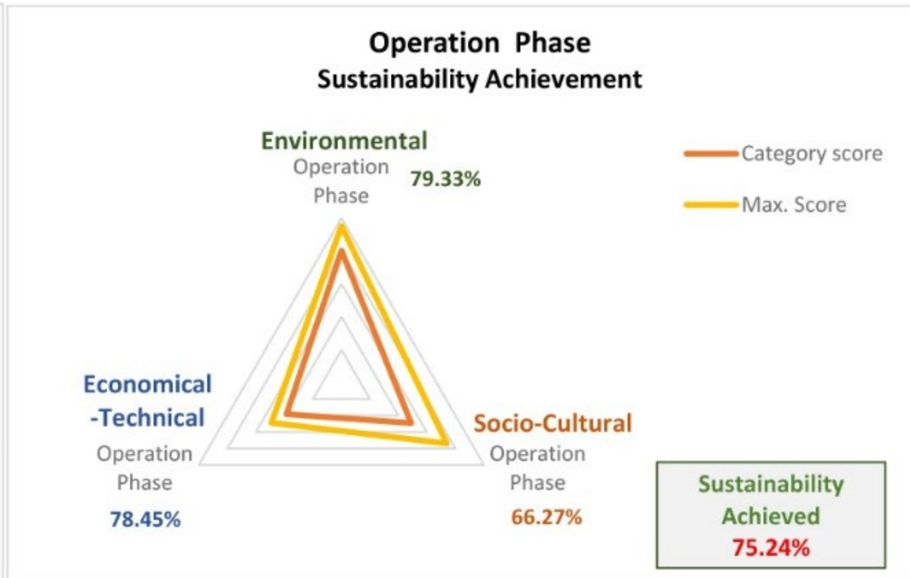
Project Title:	**10th Ramadan Wetland**
Project Type:	**Constructed Wetland Park**
Location:	**10th City, Cairo Governerate, Egypt, 30°20'17.9"N 31°47'19.2"E**
Climatic Zone:	**Arid Climate, BWh**
Hardiness Zone:	**10**
Assessment Author:	**Aya ElMeligy**

nr.	Category	Category Total Score	Max Score	Sustainability Weight from Questionnaire	Sustainability: Achieved Sustainability Score from 10	Sustainability: Maximum Sustainability Score from10	Sustainability: 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%**





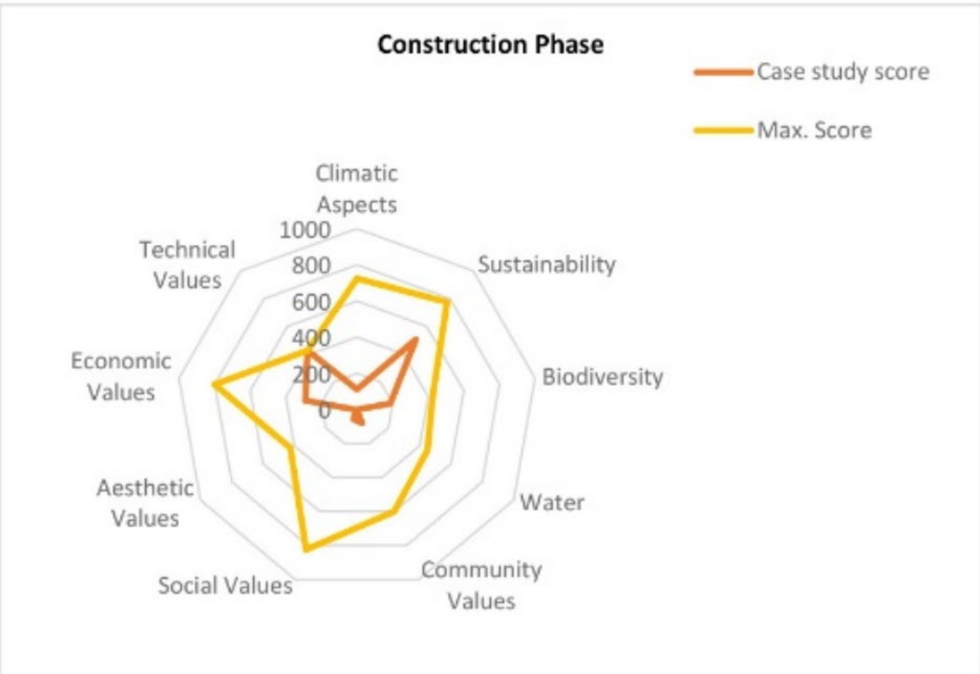


6.7.2. Categories performance Chart

Fig. (180) Wetland Park's Categories performance analysis, Source: Author

Project Title:	**10th Ramadan Wetland**
Project Type:	**Constructed Wetland Park**
Location:	**10th City, Cairo Governerate, 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	Economical Technical	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

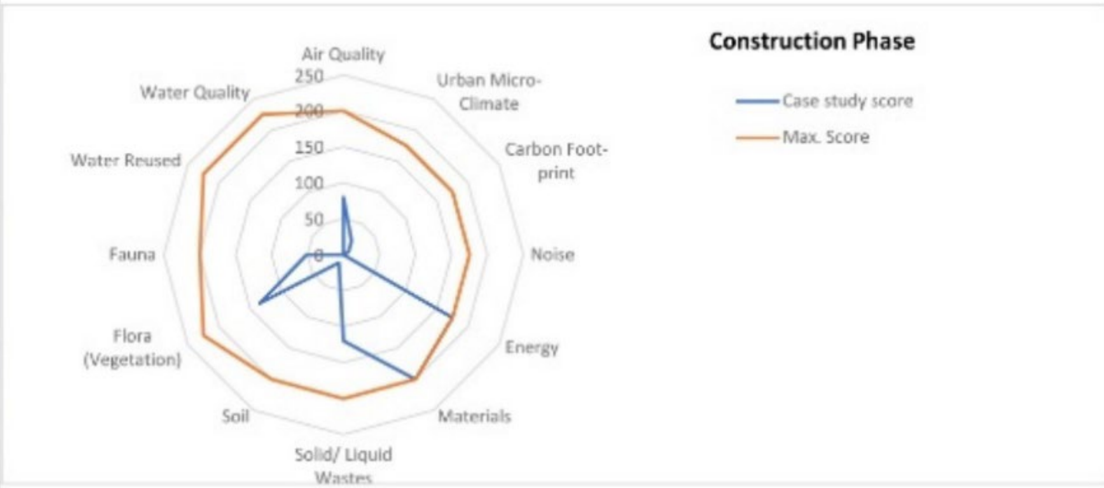
Project Title:	**10th Ramadan Wetland**
Project Type:	**Constructed Wetland Park**
Location:	**10th City, Cairo Governerate, Egypt, 30°20'17.9"N 31°47'19.2"E**
Climatic Zone:	**Arid Climate, BWh**
Hardiness Zone:	**10**
Assessment Author:	**Aya ElMeligy**

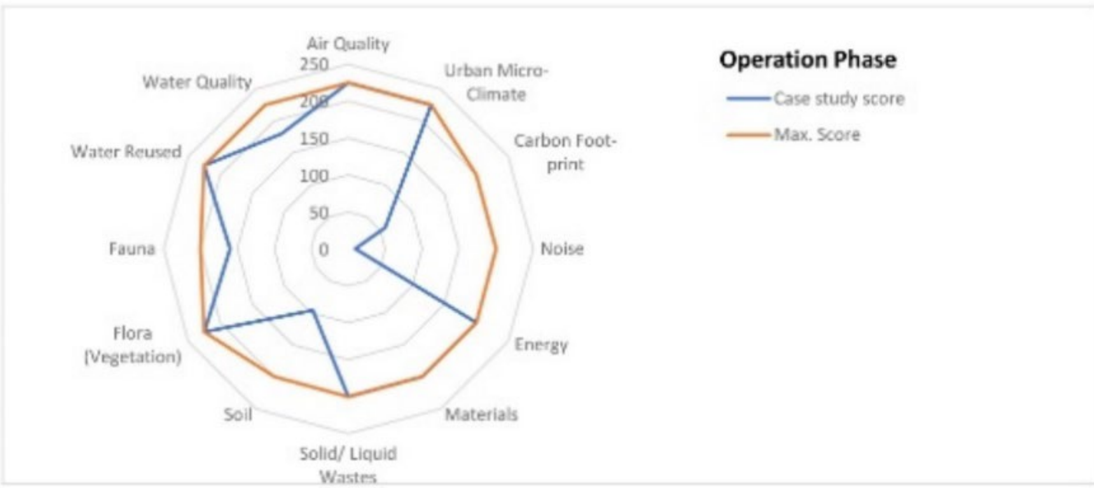
Construction Phase

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
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		Biodiversity	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		Biodiversity	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%**





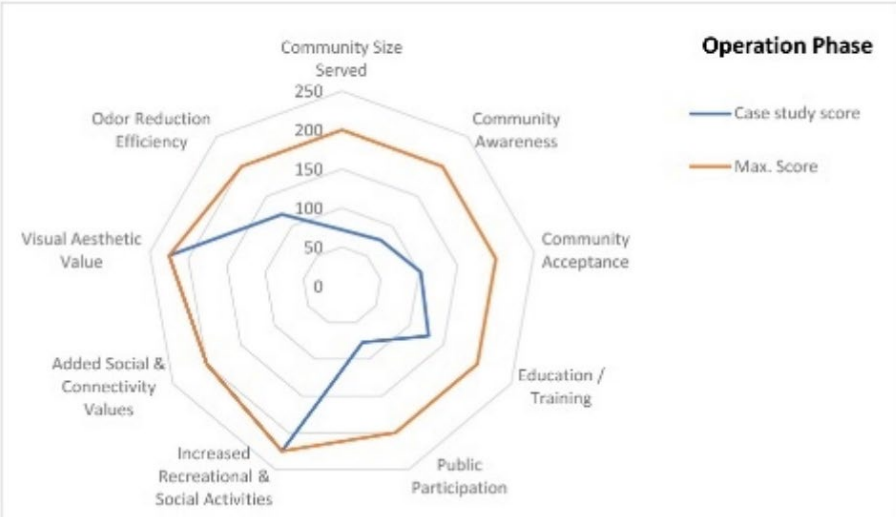
6.7.4. Socio-Cultural Impact Assessment Chart

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 Governerate, 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		Impact Factor	Construction Phase											
				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			Added Social & Connectivity Values	1	4	1	1	4	0.8	3	200	1.6			
23		Aesthetic Values	Visual Aesthetic Value	1	4	1	1	4	0.9	4	225	1.6	4	425	0.85%
24			Odor Reduction Efficiency	0	2	0	1	0	0.8	0	200	0			
			Total Socio-Cultural Value							139	1850		139	1850	7.52%

Nr.	Category		Impact Factor	Operation Phase											
				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%



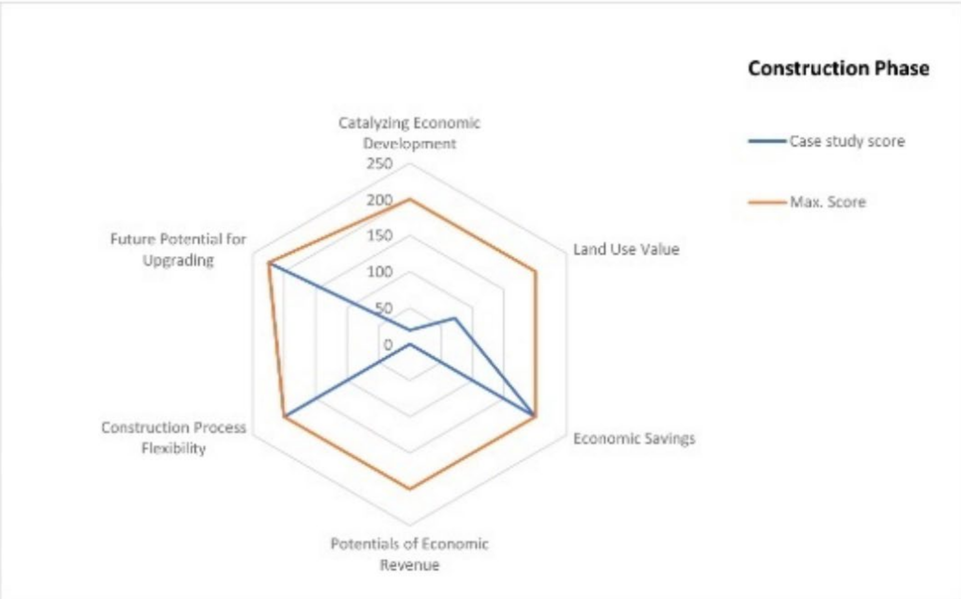
6.7.5. Economical -Technical Impact Assessment Chart

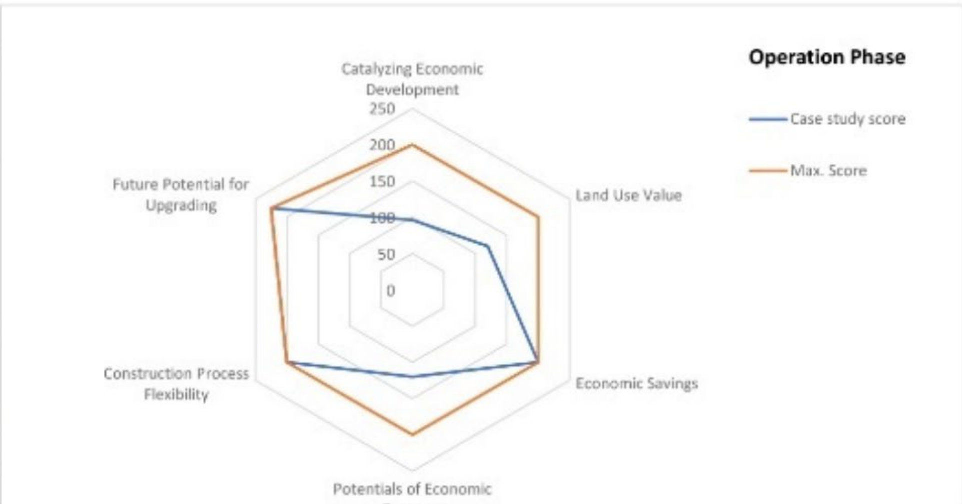
Fig. (183) Wetland Park's Economical -Technical Impact Assessment analysis, Source: Author

Project Title:	10th Ramadan Wetland
Project Type:	Constructed Wetland Park
Location:	10th City, Cairo Governerate, 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	Economical -Technical Impact Factors	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	Economical -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.

8. Bibliography

1. Aamer, W., 2011 — Biological treatment of environmental pollutants, Wafaa Mahrous Aamer, Assiut Journal of Environmental Studies - Issue 21, July 2001. http://www.aun.edu.eg/arabic/society/pdf/ajoes21_article4.pdf
2. Abhijith, K. V., et al., 2017 — Air pollution abatement performances of green infrastructure in open road and built-up street canyon environments—a review, K.V. Abhijith, Prashant Kumar, John Gallagher, Aonghus McNabola, Richard Baldauf, Francesco Pilla, Brian Broderick, Silvana Di Sabatino, Beatrice Pulvirenti, Atmospheric Environment Vol. 162, 2017 https://www.sciencedirect.com/science/article/pii/S1352231017303151?via%3Dihub
3. AbouElElla, S., 2017 — A guide for improving water quality in the drainage path using water weeds, Dr. Salwa M, AbouElElla Canal Maintenance Research Institute, May 2017 (Arabic)
4. Adel, M., et. al., 2019 — Environmental Assessment for major development projects: a case study "Qattara Depression", Marwa Adel and Walaa S.E. Ismaeel, Journal of Cleaner Production, 2019, 215, DOI:10.1016/j.jclepro.2018.12.301, https://www.researchgate.net/publication/330247801_Environmental_Assessment_for_major_development_projects_a_case_study_Qattara_Depression
5. Aide, M. et al., 2020 — Employing Constructed Wetlands to Sustainably Manage Nutrient-Bearing Water: A Review with an Emphasis on Soil Behavior and Effluent Nutrient Reduction, Michael Aide, et al., Journal of Geoscience and Environment Protection 8.09 (2020): 94.
6. Aircheckr, 2022 — Aircheckr, Air Quality Index, Date accessed: 10 January, 2022
7. AirNow.gov, 2022 — AirNow.gov - Home of the U.S. Air Quality Index, Date accessed: 10 January 2022 https://www.airnow.gov/aqi/aqi-basics/
8. AKAA, 2008 — Aga Khan Award for Architecture, AKAA, Wadi Hanifa Wetlands, 2008-2010 Cycle, 2020, Date accessed: July, 3, 2021, https://www.akdn.org/architecture/project/wadi-hanifa-wetlands
9. Akbari, H., 2002 — Shade trees reduce building energy use and CO_2 emissions from power plants, H. Akbari, Environmental Pollution 116, S119-S126, 2002.
10. Al-Asad, M. et al., 2004 — Wadi Hanifa Development Plan, Riyadh, Saudi Arabia, AKAA On Site Review Report, Mohammad al-Asad and Yildrim Yavuz, Arriyadh Development Authority, 2258 SAU, 2004, https://s3.us-east-1.amazonaws.com/media.archnet.org/system/publications/contents/1206/original/FLS1237.pdf?1384750082, Date accessed: July 3, 2021
11. Albold A. et al., 2011 — Constructed Wetlands Sustainable Wastewater Treatment for Rural and Peri-Urban Communities in Bulgaria; Case study, Andrea Albold, Claudia Wendland, Bistra Mihaylova, Alp Ergünsel, Hilda Galt, WECF, 2011 https://www.wecf.org/case-study-constructed-wetland-in-vidrare-bulgaria/
12. Almeida, S., et al., 2014 — Avaliação de impactos ambientais do processo de produção de etanol utilizando método derivado da Matriz de Leopold, Almeida, S., Santos, V., & Torres, G., Revista do Centro do Ciências Naturais e Exatas, 48(4), 1443-1459, 2014.
13. Al-Nasrawi, F. et al., 2020 — Al-Nasrawi, F.A. et al 2020, Using the Leopold Matrix Procedure to Assess the Environmental Impact of Pollution from Drinking Water Projects in Karbala City, Iraq, IOP Conference Series: Materials Science and Engineering, Volume 671, 3rd International Conference on Engineering Sciences 4–6 November 2019, Kerbala, Iraq, 671 012078, https://iopscience.iop.org/article/10.1088/1757-899X/671/1/012078
14. Al-Nimr, A., et al., 2015 — Numerical Simulation of Groundwater Flow and Contaminant Transport in the Quaternary Aquifer in 10th of Ramadan City Area, East Delta, Egypt, Ahmed Al-Amin Al-Nimr, Mohamed E. Gad, Enas, S. Hussein, Mansoura Engineering Journal, (MEJ), Vol. 40, Issue 4: [the 8th International Engineering Conference, December 2015, Part II], 2015. https://bfemu.journals.ekb.eg/article_104971_803474f05b36bdd8b5476aa301c89f3f.pdf
15. Al-Obaid, S., et al., 2017 — An overview of wetlands of Saudi Arabia: Values, threats, and perspectives, Sami Al-Obaid, Boudje´ma Samraoui, Jacob Thomas, Hamed A. El-Serehy, Ahmed H. Alfarhan, Wolfgang Schneider, Mark O'Connell, Ambio, 2017, 46(1), pp.98-108, DOI 10.1007/s13280-016-0807-4, https://link.springer.com/content/pdf/10.1007/s13280-016-0807-4.pdf
16. Alrabe, M., 2015 — The Craving Desert: Story of a Remediated Dump, Ecological Urbanism: Wadi Hanifa, AlRiyadh, Saudi Arabia, Muneerah Alrabe, SMarchs, 2015, https://web.mit.edu/nature/projects_14/pdfs/2014-WadiHanifa-Muneerah.pdf

17.	Arriyadh DA/Moriyama & Teshima/Buro Happold, 2010	Wadi Hanifah Comprehensive Development Plan, Arriyadh Development Authority/Moriyama & Teshima/Buro Happold, March 2010 https://docplayer.net/7729494-Wadi-hanifah-restoration-project-arriyadh-development-authority-moriyama-teshima-buro-happold-march-2010.html
18.	ASLA, 2018	A Landscape Performance + Metrics Primer for Landscape Architects: Measuring Landscape Performance on The Ground, Emily McCoy, American Society of Landscape Architects, ASLA, Landscape Architecture Technical Information Series, LATIS, Contributors, Marin Braco, Lauren Mandel, Landscape Architecture Technical Information Series, 2018, https://www.bcsla.org/sites/default/files/resources/files/climate-change/downloads/Landscape%20Performance%20%26%20Metrics%20Primer%20%28ASLA%29.%20%202018.pdf
19.	ASLA, Case-236, 2011	Green Infrastructure & stormwater Management, case study, South Los Angeles Wetland Park Site Plan, American Society of Landscape Architects, Case No. 236, asla.org/stormwater, 2011, Date accessed: 7 February 2022, https://www.asla.org/uploadedFiles/CMS/Advocacy/Federal_Government_Affairs/Stormwater_Case_Studies/Stormwater%20Case%20236%20South%20Los%20Angeles%20Wetland%20Park%20Site%20Plan,%20Los%20Angeles,%20CA.pdf
20.	AVI, 2021	Associazione Vivaisti Italiani, Italian Nursery Association, Species technical sheets, 2021, Date accessed, 22.12.2021, https://www.vivaistiitaliani.it/qualiviva/schede-tecniche-pdf
21.	Babu, S., 2016	Matrices in Environmental Impact Assessment, Saurab Babu, Eco-intelligent™, 2016 https://eco-intelligent.com/2016/12/10/matrices-in-environmental-impact-assessment/
22.	Babu, S., 2017	Matrices in Environmental Impact Assessment 2, Saurab Babu, Eco-intelligent™, 2017 https://eco-intelligent.com/2017/03/20/matrices-in-environmental-impact-assessment-2/#modified-graded-matrix
23.	Balkema, A. et al., 2002	Indicators for the sustainability assessment of wastewater treatment Systems, Balkema, Annelies, Preisig, Heinz, Otterpohl, Ralf, Lambert, A.J.D., 2002, Urban Water. 4.2, 10.1016/S1462-0758(02)00014-6, [accessed Dec 10, 2021], https://www.researchgate.net/publication/222171079_Indicators_for_the_sustainability_assessment_of_wastewater_treatment_Systems
24.	Baraldi et al. 2018	Report Historical Park, Bosco Albergati, Rita Baraldi, Osvaldo Facini, Luisa Neri, Giulia Carriero Gruppo di Ricerca, Relazione Parco Storico Bosco Albergati, Gruppo di Ricerca IBIMET-CNR, 2018 https://www.boscoalbergati.it/wp-content/uploads/2018/10/IBIMET-CNR-Relazione-BOSCO-ALBERGATI-25-07-18.pdf
25.	Barmelgy, H., 2013	Sustainable landscape and healing gardens: Introducing healing gardens as a deep form of sustainable landscape, Hesham M. Barmelgy, International Journal of Development and Sustainability, 2013, Vol. 2 No. 3, pp. 2051-2065, https://isdsnet.com/ijds-v2n3-29.pdf
26.	Barrow, C., 1997	Environmental and social impact assessment: an introduction, C. J. Barrow, 1997, Arnold, London, UK. https://www.dlsweb.rmit.edu.au/conenv/envi1128/Reading-Barrow.pdf
27.	Bartoldus et al. 1994	Evaluation for Planned Wetlands, C.C. Bartoldus, E.W. Garbisch, M.L.Kraus, Environmental Concern Inc., USA, 1994.
28.	Barwise, Y., et al., 2020	Designing vegetation barriers for urban air pollution abatement: a practical review for appropriate plant species selection, Yendle Barwise & Prashant Kumar, npj Clim Atmos Sci 3, 12, 2020, Dated accessed: 02 Oct 2021, https://doi.org/10.1038/s41612-020-0115-3 https://www.nature.com/articles/s41612-020-0115-3#citeas
29.	BdS, 2021	Association of German Perennial Gardeners (BdS), Date Accessed: 25 August 2021, https://www.bund-deutscher-staudengaertner.de/
30.	Bendoricchio, G., et al., 2000	Guidelines for free water surface wetland design, Giuseppe Bendoricchio, Luigi Dal Cin, Jesper Persson, EcoSys Bd. 8, 2000, https://www.researchgate.net/publication/268441082_Guidelines_for_free_water_surface_wetland_design
31.	Bernatzky, A., 1978	Tree ecology and preservation, Aloys Bernatzky, Elsevier Scientific Publishing Company,Technology & Engineering, 1978, ISBN: 9780444599384 https://www.semanticscholar.org/paper/Tree-ecology-and-preservation-Bernatzky/1334645ddcd676789e67f6214063da155bc4fd87#paper-header
32.	Biennal, An, Y., et al., 2014	Tangshan Nanhu Central Park Landscape Design, Youfeng An, Jie Hu, Lushan Lu, Xiaoyang Wang, Biennal Internacional De Paisatge Barcelona, Spain, 8A Biennal, 2014, http://www.arquitectes.cat/iframes/paisatge/fitxa/8303
33.	Blumberg, 2019	Constructed Wetlands, Ingenieurbüro Blumberg, 2019, https://www.blumberg-engineers.com/, Date accessed, 03.07.2021, https://www.blumberg-engineers.com/fileadmin/user_upload/Downloads/Flyer_ENG/Constructed_Wetlands_2019.pdf

34. Bond, A. et al., 2011 — Re-evaluating sustainability assessment: aligning the vision and the practice, Alan Bond, Angus Morrison-Saunders, 2011, Environmental Impact Assessment Review, 31 (1), 1– 7

35. Bond, A. et al., 2012 — Sustainability assessment: the state of the art, Alan Bond, Angus Morrison-Saunders & Jenny Pope, 2012, Impact Assessment and Project Appraisal, 30:1, 53-62, DOI:10.1080/14615517.2012.661974

36. Bonin, M., 2021 — Innovative Wetlands Park in South LA, Mathieu Bonin, Angeles Chapter, Sierra Club, 2021 https://angeles.sierraclub.org/news_conservation/blog/2021/06/innovative_wetlands_park_in_south_la

37. Bowd, R., et al., 2012 — The identification of potential resilient estuary-based enterprises to encourage economic empowerment in South Africa: a toolkit approach, Bowd, R., N. W. Quinn, D. C. Kotze, D. G. Hay, and M. Mander, 2012, *Ecology and Society* 17(3): 15. http://dx.doi.org/10.5751/ES-04840-170315

38. Bowd, R., et al., 2015 — Toward an analytical framework for understanding complex social-ecological systems when conducting environmental impact assessments in South Africa, Rebecca Bowd, Nevil W. Quinn, Donovan C. Kotze, 2015, Ecology and Society 20(1): 41. http://dx.doi.org/10.5751/ES-07057-200141 https://www.ecologyandsociety.org/vol20/iss1/art41/

39. Brack, C.L., 2002 — Pollution mitigation and carbon sequestration by an urban forest, C.L. Brack, Environmental Pollution 116, S195-S200, 2002.

40. Brisson, J. et al, 2009 — Maximizing pollutant removal in constructed wetlands: should we pay more attention to macrophyte species selection? Jacques Brisson, Florent Chazarenc, Science of the Total Environment 407(13), 3923-3930, 2009 https://www.researchgate.net/publication/222421383_Maximizing_Pollutant_Removal_in_Constructed_Wetlands_Should_We_Pay_More_Attention_to_Macrophyte_Species_Selection

41. Brix, H., 2003 — Plants used in constructed wetlands and their functions, Hans Brix, Department of Plant Ecology, Institute of Biological Sciences, University of Aarhus, Nordlandsvej 68, 8240 Risskov, Denmark, 2003, https://www.researchgate.net/publication/230563384_Plants_used_in_constructed_wetlands_and_their_functions

42. Bruns, 2019 — Bruns Pflanzen, Catalogue of trees and shrubs 2019/2020, Jan-Dieter Bruns, Erich Conrad, Joh. Bruns, Bad Zwischenahn, Germany, 2019

43. CABI, 2021 — CABI, improving lives by solving problems in agriculture and the environment, Date accessed: 15-25 August 2021, https://www.cabi.org/

44. Çiftçioğlu, G., et al., 2015 — Towards Sustainable Landscape Development Indicators for North Cyprus, Gülay Çetinkaya Çiftçioğlu and Nur Sözen, 2nd International Sustainable Buildings Symposium, Ankara, Turkey, 2015 http://www.isbs2015.gazi.edu.tr/belgeler/bildiriler/549-556.pdf, www.researchgate.net/publication/315046583

45. Côté Gold Project, 2015 — Côté Gold Project, 2015, Amended EIS / Final Environmental Assessment Report, Project #TC121522, https://ceaa-acee.gc.ca/050/documents/p80036/101167E.pdf

46. Cyclifier, 2013 — Qiaoyuan Water Park, Cyclifier Organization, 2013, Date accessed: 12 August 2021, https://www.cyclifier.org/project/qiaoyuan-park/

47. Davis, L., 1995 — A Handbook of Constructed Wetlands, Luise Davis, for the USDA-Natural Resources Conservation Service and the US Environmental Protection, Agency-Region III, 1995. https://www.epa.gov/sites/default/files/2015-10/documents/constructed-wetlands-handbook.pdf

48. DGNB, 2009 — Deutsche Gesellschaft für Nachhaltiges Bauen e. V., 2009: DGNB certification system. http://www.dgnb-system.de/de/system/zertifizierungssystem/

49. DGNB, 2022 — Deutsche Gesellschaft für Nachhaltiges Bauen e. V., Green Flag Award, 2022 German Sustainable Building Council http://www.dgnb-system.de/de/

50. Di-Cara, F., et al., 2020 — Environmental analysis of nursery plants and comparison with other production sectors, Di-Cara, Simona Giorgini Federico, Alexandra Munzi, Giulio Lotti, Cesaf – Agro-environmental and forestal service centre – Pistoia, 2020, https://www.piantemati.com/wp-content/uploads/2020/01/Analisi-ambientale-ENG-.pdf

51. Dickens, C., et al., 2019 — Defining and Quantifying National-Level Targets, Indicators and Benchmarks for Management of Natural Resources to Achieve the Sustainable Development Goals, Chris Dickens, Vladimir Smakhtin, Matthew McCartney, Gordon O'Brien and Lula Dahir, Sustainability 2019, 11, 462; https://doi.org/10.3390/su11020462

52. Dill, C., 1989 — Wastewater wetlands: user friendly mosquito habitats, C.H. Dill, In: HAMMER D.A. (ed.): Constructed Wetlands for Wastewater Treatment, Lewis Publishers, Chelsea, USA, 1989

53. Divisare, 2012 — Turenscape, Tianjin Qiaoyuan Wetland Park, Divisare, 2012, Date accessed: 12 August 2021, https://divisare.com/projects/206461-turenscape-tianjin-qiaoyuan-wetland-park

54. Draft EIA report, 2007 — Draft Environmental Impact Report, South Los Angeles Wetland Park project, CDM, LA DPW Engineering, 2007, Date accessed: 7 February 2022, http://clkrep.lacity.org/onlinedocs/2005/05-1231-S2_rpt_BOE_8-16-07a.pdf

55. Duarte, A., et. al., 2010 — Sustainability indicators of subsurface flow constructed wetlands in Portuguese small communities, Duarte, António AL, et al., 2010.

56. Econservation, 2017 — Econservation, Avaliação dos Impactos Ambientais. Técnico, Econservation, Estudos e Projetos Ambientais, Vitória, 2017.

57. Egypt voluntary national review, 2021 — Egypt's 2021 Voluntary National Review, The Ministry of Planning and Economic Development, 2021 https://sustainabledevelopment.un.org/content/documents/279512021_VNR_Report_Egypt.pdf

58. Elaw, 1998 — Methods Of Investigating Impacts: Matrices, 2012, https://www.scribd.com/doc/92921967/Eia-Term-Paper, ELAW (1998). Appendix B: Environmental Impact Assessment Methodologies. Date accessed: 01 December 2021, http://www.elaw.org/system/files/8+APPENDIX+B.pdf

59. ElMasry, L., 2014 — Landscape Architecture in Egypt: A Plant Guidebook for Al-Azhar Park and the City of Cairo, Dr. Laila ElSayed ElMasry, Volume II, First Edition, 2014

60. EPA, 2000 — Wastewater Technology, Fact Sheet Wetlands: Subsurface Flow, The United States Environmental Protection Agency, EPA 832-F-00-023September 2000

61. EPA, 2021 — Constructed Wetlands, Why are Wetlands Important? Wetlands and Nature, United States Environmental Protection Agency, 2021, https://www.epa.gov/wetlands/why-are-wetlands-important#:~:text=Wetlands%20can%20be%20thought%20of,all%20of%20their%20life%2Dcycle.

62. EU commission, 2021 — Nature Protection and Environmental Impact Assessment, Academy of European Law (ERA), Directorate-General for Environment, European Commission website, 2021, Date accessed: 29 Dec, 2021, https://ec.europa.eu/environment/legal/law/2/module_3_10.htm

63. Ezeah, C. et al., 2015 — Constructed Wetland Systems as a Methodology for the Treatment of Wastewater in Bucaramanga Industrial Park, Ezeah, C., Reyes, C.A.R. and Gutiérrez, J.F.C., Journal of Geoscience and Environment Protection, 2015. 10.4236/gep.2015.35001

64. FAO, 1996 — FAO, Food and Agriculture Organization of the United Nations, 1996, "Environmental Impact Assessment and Environmental Auditing in the Pulp and Paper Industry," Rome

65. Ferrini, F., 2009 — The tree in the city: resource or criticality? In Italian: L'albero in città: risorsa o criticità?, F. Ferrini, 2009. https://www.ilverdeeditoriale.com/pdf_verde/Albero%20in%20citt%C3%A0%202009.pdf http://docplayer.it/216924928-Alberi-urbani-per-migliorare-assimilazione-di-co-2-microclima-e-qualita-dell-aria.html

66. Figueiredo, R., et al., 2020 — Turbining the Leopold Matrix. International Journal of Advanced Engineering Research and Science, Figueiredo, R., Santos, V. and Ramos, J., 7(7), pp.492-505, 2020. Available from: https://www.researchgate.net/publication/343388946_Turbining_the_Leopold_Matrix [accessed Dec 01 2021]. https://dx.doi.org/10.22161/ijaers.77.56

67. Fiksel, J., et al., 2012 — Fiksel, Joseph, Eason, Tarsha, Frederickson, Herbert, A Framework for Sustainability Indicators at EPA, 2012, US Environmental Protection Agency, https://www.epa.gov/sites/default/files/2014-10/documents/framework-for-sustainability-indicators-at-epa.pdf

68. Fitzgerald, S., 2018 — The role of constructed wetlands in creating water sensitive cities, Shona K. Fitzgerald, Multifunctional Wetlands. Springer, Cham, 2018. 171-206.

69. Flagler, R.B., 1998 — Recognition of air pollution injury to vegetation: A Pictorial Atlas. Richard B. Flagler, Second Edition. Air & Waste Management Association, Pittsburgh, 1998, https://www.researchgate.net/publication/290993978_Ozone_Recognition_of_air_pollution_injury_to_vegetation

70. Friedman, D. et al., 2001 — Guidelines for Guidelines for Soil Quality Assessment in Conservation Planning, Diana Friedman, Mike Hubbs, Arlene Tugel, Cathy Seybold, Mike Sucik, United States Department of Agriculture USDA, Natural Resources Conservation Services, Soil Quality Institute, 2001 https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_050963.pdf

71. Gaber, R., 2020 — Implementation of Constructed Wetlands Landscape Design, A Resilient Application, Rasha Mahmoud Gaber, Faculty of Urban & Regional Planning, Cairo University Journal of Urban Research, Vol. 36, April 2020. https://jur.journals.ekb.eg/article_90104_beeb063ed39d60352c7d74bd9e4bc007.pdf

72. GAIA Project, 2015 — Green Areas Inner-city Agreement "GAIA", Bologna, Italy https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n_proj_id=3752#habitats, https://climate-adapt.eea.europa.eu/metadata/case-studies/gaia-green-area-inner-city-agreement-to-finance-tree-planting-in-bologna

73. Gallagher et al., 2015 — Passive methods for improving air quality in the built environment: a review of porous and solid barriers, Gallagher, J. et al., Atmos. Environ. 120, 2015, 61–70.

74. Gan, X., et al. 2017 — When to use what: Methods for weighting and aggregating sustainability indicators, Xiaoyu Gan , Ignacio C. Fernandez , Jie Guo, Maxwell Wilson , Yuanyuan Zhao , Bingbing Zhou , Jianguo Wu, Ecological Indicators, Volume 81, 2017, Pages 491-502, http://leml.la.asu.edu/jingle/Wu-Publications-PDFs/2017/Gan_etal-2017-When%20to%20use%20what-Methods%20for%20weighting%20and%20aggregating%20sustainability%20indicators.pdf

75. Gardeners' World, 2021 — Gardeners' World.com, by Immediate Media Company Limited under licence from BBC Studios Distribution. Date accessed: 15-25 August 2021, https://www.gardenersworld.com/

76. Gardenia, 2021 — Gardenia Creating Gardens, Date Accessed: 25 August 2021, https://www.gardenia.net/search

77. Gerhold, H., 2001 — Carbon storage by utility-compatible trees. H.D. Gerhold, Journal of Arboriculture 27, 2001

78. GFA 2016 — Green Flag Award, www.greenflagaward.org.uk

79. Glasson, J. et al., 2005 — Introduction to environmental impact assessment, Glasson, J., R. Therivel, and A. Chadwick. 1994, 1999, Fourth edition. Taylor and Francis, New York, USA, University College London (UCL) Press, the Taylor & Francis e-Library, 2005. ISBN 0-203-97960-5 Master e-book ISBN https://eia-course.cug.edu.cn/__local/B/D0/5B/B788AF4559D3356C3C18EA56C98_3F163406_5EFC12.pdf

80. Great Merce, TMA, 2022 — Great Merce, TMA, https://gmtma.org/air-quality/air-quality-index-chart/

81. Haron, A. et al., 2020 — Constructed Wetland Parks: A Pathway to Sustainability for Cairo, Ahmed Haron, Zeinab Feisal, Journal of Urban Research 36.1 (2020): 61–81. Web. https://doi.org/10.21608/JUR.2020.90103

82. Hedges, P., et al., 2008 — The Hydrological Sustainability of Constructed Wetlands for Wastewater Treatment. Peter D. Hedges, Phil M. Fermor, Jiří Dušek, In: Vymazal J. (eds) Wastewater Treatment, Plant Dynamics and Management in Constructed and Natural Wetlands. Springer, Dordrecht, 2008 https://doi.org/10.1007/978-1-4020-8235-1_10

83. Heers, M., 2006 — Constructed wetlands under different geographic conditions: Evaluation of the suitability and criteria for the choice of plants including productive species. Martin Heers, Master thesis, Faculty of Life Sciences, Hamburg University of Applied Sciences, Germany, April 2006 https://www.susana.org/_resources/documents/default/2-953-en-constructed-wetlands-under-different-geographic-conditions-2006.pdf

84. Hegazy, I., et al., 2017 — Towards green cities in developing countries: Egyptian new cities as a case study, Ibrahim Hegazy, Wael Seddik and Hossam Ibrahim, *International Journal of Low-Carbon Technologies*, Volume 12, Issue 4, December 2017, Pages 358–368, https://doi.org/10.1093/ijlct/ctx009 https://academic.oup.com/ijlct/article/12/4/358/3868475?login=true

85. Hoffmann, H., 2011 — Technology review of constructed wetlands, Dr. Heike Hoffmann, Dr.-Ing. Christoph Platzer, Dr.-Ing. Martina Winker, Dr. Elisabeth von Muench, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Sustainable sanitation - ecosan program, 2011. https://www.susana.org/_resources/documents/default/2-930-giz2011-en-technology-review-constructed-wetlands.pdf

86. Hulley, M., 2012 — The urban heat island effect: causes and potential solutions, Michael E. Hulley, in Metropolitan Sustainability, 2012, DOI: https://doi.org/10.1533/9780857096463.1.79 Date accessed: 17 November, 2021, https://www.sciencedirect.com/topics/engineering/albedo

87. Hunter, R., et al., 2018 — Hunter, Rachael G., et al. "Using natural wetlands for municipal effluent assimilation: a half-century of experience for the Mississippi River Delta and surrounding environs." Multifunctional wetlands. Springer, Cham, 2018. 15-81.

88. IBIMETCNR, 2015 — Institute of Biometeorology (IBIMET), CNR, Italy, 2015, https://www.ibe.cnr.it/

89. IISD, 2021 — International Institute for sustainable development, IISD, The 7 Steps to an EIA, Canada, 2021 https://www.iisd.org/learning/eia/eia-7-steps/step-3-impact-assessment-and-mitigation/

90. INHabitat, 2013 — Turenscape Architects Turns a 54-Acre Garbage Dump into a Luscious Low-Maintenance Park in China, Ana Lisa, INHabitat, 2013, Date accessed: 12 August 2021, https://inhabitat.com/turenscape-architects-turns-a-54-acre-garbage-dump-into-luscious-low-maintenance-park-in-china/

91. IQ Air, 2022 — IQ Air online website, Date accessed: 10 and 19 January 2022, https://www.iqair.com/egypt/cairo/new-cairo

92. Iyer, V., 2020 — Social Health Impact Assessment (Shia) Process for Coronavirus' Impacts Towards Sustainable Development, Vijayan Gurumurthy Iyer, 2020 https://www.researchgate.net/publication/340663992_social_health_impact_assessment_shia_process_for_coronavirus%27_impacts_towards_sustainable_development

93. Josimović, B., et al., 2014 The Use of the Leopold Matrix in Carrying Out the EIA for Wind Farms in Serbia, Josimović, B., Petric J., Milijic S., Energy and Environment Research 4(1): 41-54. E-ISSN 1927-0577, 2014 https://www.researchgate.net/publication/312466525_The_Use_of_the_Leopold_Matrix_in_Carrying_Out_the_EIA_for_Wind_Farms_in_Serbia, [accessed Sep 22, 2021].

94. Kadlec, J. A., 1993 Effect of depth of flooding on _ summer water budgets for small, diked marshes. Wetlands, J. A. Kadlec, 1993.

95. Kadlec, R., et al., 1996 Treatment Wetlands, R.H. Kadlec, R.L.Knight, CRC Press-Lewis Publishers, New York, 1996.

96. Kamau, C., 2009 Constructed wetlands: potential for their use in treatment of grey water in Kenya. Cynthia Gitiri Kamau, MSc thesis, Christian-Albrechts University, Kiel, Germany. https://www.susana.org/_resources/documents/default/2-950-en-constructed-wetlands-potential-for-use-2009.pdf

97. Kassim, T. et al., 2005 Environmental impact assessment of recycled wastes on surface and ground waters, T.A. Kassim, and K. J. Williamson, 2005, Volume 3: Engineering modeling and sustainability. The handbook of environmental chemistry, water pollution series. Vol. 5/Part F. Springer-Verlag, Berlin, Germany.

98. KCET, 2012 Innovative Wetlands Park Opens in South Los Angeles, Ed Fuentes, KCET, 2012 Date accessed: 7 February 2022, https://www.kcet.org/history-society/innovative-wetlands-park-opens-in-south-los-angeles

99. Knight, 1997 Wildlife Habitat and Public Use Benefits of Treatment Wetlands, Robert Knight, Water Science & Technology 35(5), 1997, DOI: 10.1016/S0273-1223(97)00050-4, https://www.researchgate.net/publication/250141396_Wildlife_Habitat_and_Public_Use_Benefits_of_Treatment_Wetlands

100. Knight, R. et al., 1990 Design of the fort deposit, Alabama constructed wetlands treatment system, Robert Knight, M.E. Iverson, In: Cooper P.F. & Findlater B.C. (eds.): Constructed wetlands in water pollution control. Pergamon Press, Oxford, UK, 1990.

101. Konarska, J. et al., 2015 Transpiration of urban trees and its cooling effect in a high latitude city, Janina Konarska, Johan Uddling, Björn Holmer, Martina Lutz, Fredrik Lindberg, Håkan Pleijel, Sofia Thorsson, International Journal of Biometeorology, 2015 DOI: 10.1007/s00484-015-1014-x, https://www.researchgate.net/publication/277817395_Transpiration_of_urban_trees_and_its_cooling_effect_in_a_high_latitude_city

102. Kourtzanidis, K., 2021 Assessing Impact, Performance and Sustainability Potential of Smart City Projects: Towards a Case Agnostic Evaluation Framework. Konstantinos Kourtzanidis, Komninos Angelakoglou, Vasilis Apostolopoulos, Paraskevi Giourka, and Nikolaos Nikolopoulos, Sustainability 2021, 13, 7395. https://doi.org/10.3390/su13137395

103. LAF, 2018 Evaluating Landscape Performance: A Guidebook for Metrics and Methods Selection, Landscape Performance Series, 2018, https://www.landscapeperformance.org/guide-to-evaluate-performance

104. Landezine, 2011 Tianjin Qiaoyuan, Landezine Landscape Architecture Platform, 2011, Date accessed: 12 Aug. 2021, https://landezine.com/tianjin-qiaoyuan-park-by-turenscape-landscape-architecture/

105. LAParks, 2022 South Los Angeles Wetlands Park, City of Los Angeles Department of Recreation and Parks, https://www.laparks.org/park/south-los-angeles-wetlands-park, Date accessed: 7 February 2022

106. Lee, H.-S., et al., 2020 Developing a Landscape Sustainability Assessment Model Using an Analytic Hierarchy Process in Korea, Hyung-Sook Lee and Park Eun-Yeong, 2020, Sustainability 12, no. 1: 301 https://doi.org/10.3390/su12010301

107. Leopold, L. B. et al, 1971 A procedure for evaluating environmental impact, Luna Bergere Leopold, Frank Eldridge Clarke, Bruce B. Hanshaw, and James R. Balsley, U.S. Geological Survey Circular 645, Washington, D.C., 1971. https://doi.org/10.3133/cir645, https://pubs.er.usgs.gov/publication/cir645

108. Lexology, 2019 Egypt: Environmental Impact Assessment System (EIA), Lexology, Youssry Saleh & Partners, Lexology, 2019, Accessed: 15 April 2021, https://www.lexology.com/library/detail.aspx?g=fbf4853e-218e-4a93-9ea7-eaa568811602

109. Li, M., et al., 2012 Tangshan Nanhu Eco-City Central Park – Tangshan City, China, Methodology for Landscape Performance Benefits, Ming-Han Li, Bruce Dvorak, Yi Luo, Landscape Ecology, Landscape Architecture Foundation, 2012 https://www.landscapeperformance.org/sites/default/files/Tangshan%20Nanhu%20Methodology_1.pdf

110. Li, X., 2003 Sustainable Development Principles for East Baton Rouge Parish, A Thesis of Master of Landscape Architecture, Li, X., Louisiana State University, 2003.

111. Lohani, B., et al., 1997 Environmental Impact Assessment for Developing Countries in Asia, Lohani, B., J.W. Evans, H. Ludwig, R.R. Everitt, Richard A. Carpenter, and S.L. Tu, Volume 1 - Overview. 356 pp., 1997, https://www.adb.org/sites/default/files/publication/29779/eia-developing-countries-asia.pdf

112. LPS-CSB- 424, 2011 Landscape Performance Series, The LPS Case Study Briefs, CSB The Landscape Architecture Foundation, LAF: Case-study=424, 2011, Date accessed: 6 August 2021, https://doi.org/10.31353/cs0170, https://www.landscapeperformance.org/case-study-briefs/shanghai-houtan-park

113. LPS-CSB- 425, 2011 Landscape Performance Series, The LPS Case Study Briefs, CSB The Landscape Architecture Foundation, LAF: Case-study=425, 2011, Date accessed: 12 August 2021, https://doi.org/10.31353/cs0180, https://www.landscapeperformance.org/case-study-briefs/tianjin-qiaoyuan-park-the-adaptation-palettes

114. LPS-CSB- 494, 2012 Tangshan Nanhu Eco-city Central Park, Dvorak, Bruce, Ming-Han Li, and Yi Luo, Landscape Performance Series, The LPS Case Study Briefs, CSB The Landscape Architecture Foundation, LAF: Case-study=494, 2012, https://doi.org/10.31353/cs0300 https://www.landscapeperformance.org/case-study-briefs/tangshan-nanhu-eco-city-central-park

115. LPS-CSB-1015, 2015 Wadi Hanifah Comprehensive Development Plan, Trottier, Jean, and Kevin Eidick, Landscape Performance Series, The LPS Case Study Briefs, CSB The Landscape Architecture Foundation, LAF: Case-study=1015, 2015, https://doi.org/10.31353/cs1040, https://www.landscapeperformance.org/case-study-briefs/wadi-hanifah; https://www.landscapeperformance.org/case-study-briefs/riyadh-bioremediation-facility

116. LPS-CSB- 1041, 2016 Landscape Performance Series, The LPS Case Study Briefs, CSB The Landscape Architecture Foundation, LAF: Case-study= 1041, 2016, Date accessed: 6 August 2021, https://doi.org/10.31353/cs1130, https://www.landscapeperformance.org/case-study-briefs/south-la-wetland-park

117. Ma, W., MIT, 2014 Design Paths to Ecological Urbanism by Kongjian Yu Comparative Case Studies of Zhongshan Shipyard Park and Tianjin Qiaoyuan Park, Wenji Ma, MIT Edu, 2014, Date accessed: 12 August 2021, https://web.mit.edu/nature/projects_14/pdfs/2014-KonjianYuChinaCases-Ma.pdf

118. Malachite S. S., 2017 Malachite Specialist Services, Broad Scale Wetland Impact Assessment, Malachite Specialist Services (Pty) Ltd, Durban, 2017, [accessed Apr 23 2021]. https://www.nsovo.co.za/publication/2018/Project%202/2018-08-01%20-%20My%20Transfer%20(5)/Appendix%20C7%20-%20Wetland%20Report/17-028%20Inyaninga-Mbewu%20Powerline%20project%20Wetland%20Assessment%20Report%20(2)%20-%2014092017.pdf

119. Martim, H., et al., 2013 Martim, H., & Santos, V., Avaliação de impactos ambientais em empresa de mineração de cobre utilizando redes de interação.Revista Eletronica em Gestão, Educação e Tecnologia Ambiental - REGET, pp. 3246-3257, 2013.

120. Martin, C., et al., 1989 California's experience with mosquitoes in aquatic wastewater treatment systems, C.V. Martin, B.F. Eldridge, In: HAMMER D.A. (ed.): Constructed wetlands for wastewater treatment, Lewis Publishers, Chelsea, USA, 1989

121. McCartney M., et al., 2015 Wetlands, Livelihoods and Human Health, Matthew P. McCartney, Lisa-Maria Rebelo and Sonali Senaratna Sellamuttu, In: Wetlands and Human Health. Wetlands: Ecology, Conservation and Management. Vol. 5., editors: C Max Finlayson, Pierre Horwitz, Philip Weinstein, Dordrecht: Springer; 2015, https://link.springer.com/content/pdf/10.1007%2F978-94-017-9609-5.pdf

122. McPherson et al., 1994 Chicago's urban forest ecosystem: results of the Chicago Urban Forest Climate Project. E.G. McPherson, D.J. Nowak, R.A. Rowntree, General Technical Report Northeastern Forest Experiment Station, USDA Forest Service, 1994, No. NE-186, 201 pp.

123. Minnesota Wildflowers, 2021 Minnesota Wildflowers: A Project for Environmental Justice, Date accessed: 15-25 August 2021, https://www.minnesotawildflowers.info

124. Mohamed, A., 2004 Planung, Bau und Betrieb einer Pflanzenkläranlage in Syrien (Planning, construction and operation of a constructed wetland in Syria). Abir Mohamed, PhD thesis, University Flensburg, Germany https://www.susana.org/_resources/documents/default/2-948-de-pflanzenklaeranlage-syrien-2004.pdf

125. Mohamed, H. et al., 2014 Efficiency of Constructed Wetlands in Arid Regions, Dr. Haga Osman Mohamed, Dr. Hanan Osman Ali, International Journal of Engineering Innovation & Research, Volume 3, Issue 5, 2014 https://1library.net/document/zlep8llq-efficiency-of-constructed-wetlands-in-arid-regions.html

126. Moraes, C. et al., 2016 Moraes, C., & Aquino, C., Avaliação de impacto ambiental: uma revisão da literatura sobre as principais metodologias. 5º Simpósio de Integração Científica e Tecnológica do Sul Catarinense – SICT-Sul., 2016.

127. Muga H., et. al., 2008 — Sustainability of wastewater treatment technologies, Helen E. Muga, James R. Mihelcic, Journal of environmental management 88.3 (2008): 437-447. https://www.sciencedirect.com/science/article/pii/S0301479707001028

128. Müller, N. et al. 2016 — Proceedings URBIO Index Workshop, Norbert Müller and Katja Elsner, Fachhochschule Erfurt, Editor: University of applied sciences Erfurt, Department Landscape Management and restoration Ecology, Germany, 2016, Date Accessed 5 Nov., 2021, https://www.researchgate.net/publication/330727824_Proceedings_URBIO_Index_Workshop_2016

129. Municipality of Carimate, 2017 — Abacus Agronomic Report of essences, Municipality of Carimate (CO), Relazione agronomica abaco delle essenze, Comune di Carimate. 2017.

130. Munn, R., 1979 — Munn, R. E. 1979. Environmental impact assessment: principles and procedures. SCOPE Report 5. Second edition. John Wiley, Chichester, UK. https://books.google.com/books?hl=en&lr=&id=zfwbBQAAQBAJ&oi=fnd&pg=PA135&ots=VMY37kQ4qV&sig=bvbvqZji87-Ks0O0eqj7N3qJjbw#v=onepage&q&f=false

131. Mureșan, M., 2012 — Optimal Treatment Technology for Rural Wastewater: Constructed Wetlands, Mircea Mureșan, 2012.https://www.researchgate.net/publication/275768829_OPTIMAL_TREATMENT_TECHNOLOGY_FOR_RURAL_WASTEWATER_CONSTRUCTED_WETLANDS

132. Muslem M. et al, 2010 — Muslem M., Homod J., Mohammad Selman H, 2010, Environmental Impact Application Assessment and Its Application to The Middle Euphrates Region, Babylon Univ. J. Eng. Sci., vol. 2, no. 18, https://www.researchgate.net/publication/326069187_Environmental_Impact_Assessment_and_Its_Application_in_the_Middle_Euphrates_Region, [Date accessed Oct 05 2021].

133. NC Extension, 2021 — The North Carolina Extension Gardener Plant Toolbox, NC State, Plants.CES., Date accessed: 15-25 August 2021, https://plants.ces.ncsu.edu/

134. Nicese & Lazzerini 2013 — CO_2 Sources and Sink in Ornamental Plant Nurseries. Proc. IIIS on Woody Ornamentals of the Moderate Zone. F.P. Nicese, G. Lazzerini, Acta Hort. 990, ISHS, 2013.

135. Nikolić, V., et al., 2009 — Wetlands, constructed wetlands and theirs role in wastewater treatment with principles and examples of using it in Serbia, Vladimir Nikolić, Dragan Milicevic, Slobodan Milenković, Facta Universitatis - series: Architecture and Civil Engineering. 7., 2009, 10.2298/FUACE0901065N https://www.researchgate.net/publication/47393569_Wetlands_constructed_wetlands_and_theirs_role_in_wastewater_treatment_with_principles_and_examples_of_using_it_in_Serbia

136. Nowak, D., 1994 — Air Pollution Removal by Chicago's Urban Forest, In: Gregory E. McPherson, David J. Nowak, Rowan A. Rowntree, (Eds.) Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project. USDA Forest Service General Technical Report NE-186, Radnor, PA, 1994, pp. 63–82

137. Nowak, D., et al., 1997 — Nowak DJ, McHale PJ, Ibarra M, Crane D, Stevens JC, Luley CJ 1997. Modeling the effects of urban vegetation on air pollution. In: 22nd NATO / CCMS International Technical Meeting on Air Pollution Modeling and its Application, NATO / CCMS, Brussels: 276-282.

138. Nowak, D., et al. 2002 — Nowak DJ, Stevens JC, Sisinni SM, Luley CJ 2002d. Effects of urban tree management and species selection on atmospheric carbon dioxide. Journal of Arboriculture 28, 113-122.

139. Nowak, D., et al. 2007 — Oxygen Production by Urban Trees in the United States, David J. Nowak, Robert Hoehn, Daniel E. Crane, Arboriculture & Urban Forestry, 33 (3), 2007, 220–226.

140. NRC, 2010 — National Research Council 2010. Toward Sustainable Agricultural Systems in the 21st Century. Washington, DC: The National Academies Press. https://doi.org/10.17226/12832. [accessed Dec 11, 2021].

141. Omondi, D., 2017 — Wastewater Management Techniques: A Review of Advancement on the Appropriate Wastewater Treatment Principles for Sustainability. Environmental Management and Sustainable Development. Omondi, Donde Oscar, 2017, 6. 40. DOI: 10.5296/emsd.v6i1.10137 https://www.researchgate.net/publication/314865308_Wastewater_Management_Techniques_A_Review_of_Advancement_on_the_Appropriate_Wastewater_Treatment_Principles_for_Sustainability

142. Omondi, D. et al., 2018 — Efficacy of macrophyte dominated wastewater enclosure as post-treatment alternative in domestic wastewater quality polishing for eradication of faecal pathogenic bacteria pollution. Omondi, Donde Oscar; Cuicui T., Yingying T., Bangding X., 2018, Process Safety and Environment Protection. http://dx.doi.org/10.1016/j.psep.2017.12.023

143. Omondi, D. et al., 2020 — Constructed Wetlands in Wastewater Treatment and Challenges of Emerging Resistant Genes Filtration and Reloading; Omondi, Donde Oscar and Navalia, Atalitsa Caren; 2020, Intech Open: London, UK. Doi: 10.5772/intechopen.93293 https://www.researchgate.net/publication/343945152_Constructed_Wetlands_in_Wastewater_Treatment_and_Challenges_of_Emerging_Resistant_Genes_Filtration_and_Reloading

144. Pakzad, P. et al., 2017 — Parisa Pakzad, Paul Osmond, Linda Corkery, 2017. Developing Key Sustainability Indicators for Assessing Green Infrastructure Performance, Procedia Engineering 180, DOI: 10.1016/j.proeng.2017.04.174, https://www.researchgate.net/publication/317136321_Developing_Key_Sustainability_Indicators_for_Assessing_Green_Infrastructure_Performance

145. Pavlovskaia, E., 2014 — Evgenia Pavlovskaia (2014) Sustainability criteria: their indicators, control, and monitoring (with examples from the biofuel sector) Environ Sci Eur. 2014; 26(1): 17. Published online 2014 Jul doi: 10.1186/s12302-014-0017-2, [accessed Dec 11, 2021], https://www.researchgate.net/publication/275500585_Sustainability_criteria_their_indicators_control_and_monitoring_with_examples_from_the_biofuel_sector

146. Pomerantz, M., et al., 2000 — The Effect of Pavements' Temperatures on Air Temperatures in Large Cities, Pomerantz, M., B. Pon, H. Akbari, and S.-C. Chang. Paper LBNL-43442. Lawrence Berkeley National Laboratory, Berkeley, CA, 2000, Date accessed: 17 November, 2021, https://escholarship.org/content/qt6ss5g0wg/qt6ss5g0wg_noSplash_518f17068d08088d75b426f7f6b91be6.pdf?t=p21mw9

147. Ponce, V., 2009 — The Leopold Matrix for Evaluating Environmental Impact, Dr. Victor M. Ponce, 2009, [accessed Sep 22 2021]. http://ponce.sdsu.edu/the_leopold_matrix.html

148. Preliminary Design Report, 2008 — Preliminary Design Report – South Los Angeles Wetland Park, Final Proposition O, Psomas, 2008 https://www.yumpu.com/en/document/view/4569889/preliminary-design-report-proposition-o

149. Psomas, 2014 — South LA Wetland Park, Beautiful Park on Former Brownfield Site, Psomas, 2014, Date accessed: 7 February 2022, https://psomas.com/projects/south-los-angeles-wetland-park/

150. Qualivivia Project, A8, G3, 2011 — Ministry of Agricultural, Food and Forestry Policies, Qualiviva project, Action 8 - Local Guidelines, Guideline 3: Effect of Urban Forests on Air Quality, Italy, 2011 https://www.politicheagricole.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/9785#

151. Qualivivia Project, A8, G4, 2011 — Ministry of Agricultural, Food and Forestry Policies, Qualiviva project, Action 8 - Local Guidelines, Guidelines 4: ornamental tree species resistant to the main diseases

152. Rai, P., 2012 — An eco-sustainable green approach for heavy metals management: two case studies of developing industrial region, P. K. Rai, 2012, *Environmental Monitoring and Assessment*, *184*(1), 421-448.

153. RBG Kew, 2021 — Royal Botanic Gardens, Plants of the World Online, Date accessed: 15-25 August 2021, http://powo.science.kew.org/

154. RCRC, 2020 — Environmental Rehabilitation Program for Wadi Hanifa and its Tributaries, Royal Commission for Riyadh City, RCRC, Date accessed: June 19, 2020 https://www.rcrc.gov.sa/en/projects/wadi-hanifah

155. Refaat, D., et al., 2019 — Urban regeneration of "SoorMagra AL Oyoon" district. Darin Refaat, Mohamed Zaki, Aya ElMeligy, Rasha Gaber, Gehan El-Sayed, Ayman Abd El Hamid, IEREK Press, 2019 https://www.researchgate.net/publication/335582795_Urban_regeneration_of_SoorMagra_AL_Oyoon_district

156. Richter et al., 2011 — Leitfaden Nachhaltiges Bauen – Außenanlagen, Richter, Elke, Loidl-Reisch Cordula; Brix, Karen, Zelt, Jennifer; Zimmermann, Astrid, LA.BAR Landschaftsarchitekten bdla, Berlin, 2011, http://www.planen-bauen-umwelt.tu-berlin.de/fileadmin/fg237/EndberichtLeitfadenNachhaltigesBauenAussenanlagen2011.pdf

157. Robati, M., et al., 2021 — Evaluation and ranking of urban sustainability based on sustainability assessment by fuzzy evaluation model, Maryam Robati, F. Rezaei, International Journal of Environmental Science and Technology, 2021 DOI:10.1007/s13762-021-03128-1 https://www.semanticscholar.org/paper/Evaluation-and-ranking-of-urban-sustainability-on-Robati-Rezaei/71fe1c2fdb82fcd1418d70542d0c54370ee60d83

158. Rosenfeld et al., 1998 — Mitigation of urban heat islands materials, utility programs, updates, A.H. Rosenfeld, H. Akbari, S. Bretz, B.L. Fishman, D.M. Kurn, D. Sailor, H. Taha, Energy and Building 22, 255-265. Rosenfeld, 1995.

159. Rottle, N., & Lacson, 2011 — Tianjin Qiaoyuan Park: The Adaptation Palettes – He Dong Qu Tianjin, China Methodology for Landscape Performance Benefits, Nancy Rottle and Delia Lacson, Landscape Performance Series, Landscape Architecture Foundation, 2011, https://www.landscapeperformance.org/sites/default/files/Qiaoyuan%20Park%20Methodology.pdf

160. Rottle, N., et al., 2011 — Shanghai Houtan Park – Shanghai, China, Methodology for Landscape Performance Benefits, Nancy Rottle, Delia Lacson, Peter Cromwell, Ying-Ju Yeh, and Chen Hai, Landscape Performance Series, Landscape Architecture Foundation, 2011, Date accessed: 6 August 2021, https://www.landscapeperformance.org/sites/default/files/Shanghai%20Houtan%20Park%20Methodology.pdf

161. Saad, S., et al., 2017 — Development of indoor environmental index: Air quality index and thermal comfort index S. M. Saad, A. Y. M. Shakaff, A. R. M. Saad, A. M. Yusof, A. M. Andrew, A. Zakaria, and A. H. Adom, AIP Conference Proceedings 1808, 020043 (2017); doi: http://dx.doi.org/10.1063/1.4975276 https://www.researchgate.net/publication/315006128_Development_of_indoor_environmental_index_Air_quality_index_and_thermal_comfort_index/figures?lo=1, Date accessed: 10 Jan, 2022

162. Salama, N. et al., 2015 — Edge, Center, and Spine: Exploring the Multi-Dimentionality of Contemporary Landscapes in Middle Eastern Cities, Ashraf M. Salama, Anna Grichting, International Journal of Architectural Research Archnet-IJAR 9(2):113-136, https://www.researchgate.net/publication/282739491_Edge_Center_and_Spine_Exploring_the_Multi-Dimentionality_of_Contemporary_Landscapes_in_Middle_Eastern_Cities

163. Samhouri, W., 2010 — Wadi Hanifa Wetlands, Riyadh, Saudi Arabia, AKAA On Site Review Report, Wael Samhouri, Arriyadh Development Authority, 2258 SAU, 2010, https://www.archnet.org/ http://www.landscape.cn/special/Aga-Khan/images/0001.pdf

164. Sandham, L., et al., 2019 — The quality of environmental impact reports for projects with the potential of affecting wetlands in South Africa, Sandham, L. A., Moloto, M. J., & Retief, F. P., Water SA, 34(2), 155, 2019, [accessed Apr 23 2021]. https://doi.org/10.4314/wsa.v34i2.183635 https://www.ajol.info/index.php/wsa/article/view/183635/172992

165. SDR2021, Sachs, J., et al., 2021 — Sustainable Development Report 2021 The Decade of Action for the SDGs, Jeffrey D. Sachs, Christian Kroll, Guillaume Lafortune, Grayson Fuller, and Finn Woelm, Cambridge University Press, University Printing House, Cambridge CB2 8BS, United Kingdom, 2021, doi.org/10.1017/9781009106559, ISBN 978-1-009-09891-5 Hardback, https://dashboards.sdgindex.org/profiles/egypt-arab-rep https://s3.amazonaws.com/sustainabledevelopment.report/2021/2021-sustainable-development-report.pdf

166. Secretariat of the CBD, 2006 — Biodiversity in Impact Assessment, Background Document to CBD Decision VIII/28: Voluntary Guidelines on Biodiversity-Inclusive Impact Assessment, Secretariat of the Convention on Biological Diversity, Netherlands Commission for Environmental Assessment, Montreal, Canada, CBD Technical Series No.26, 2006 https://www.cbd.int/doc/publications/cbd-ts-26-en.pdf

167. Seidel, 1965 — New methods for groundwater recharge in Krefeld – Part 2: hydrobotanical treatment method). Klaus Seidel, GWF Wasser Abwasser 30, 1965, pp. 831-833

168. Selman, P., 2008 — What do We Mean by Sustainable Landscape? Paul Selman, 2008, Sustainability: Science, Practice, & Policy (4):2: 23-28 https://www.tandfonline.com/doi/abs/10.1080/15487733.2008.11908019

169. Shannon, K., et al., 2016 — Shannon, Kelly, and Christina Hood. “South Los Angeles Wetland Park.” Landscape Performance Series. Landscape Architecture Foundation, 2016. https://www.landscapeperformance.org/sites/default/files/South%20LA%20Wetland%20Park%20Methodology.pdf

170. SITES, 2016 — Sustainable Sites Initiative www.sustainablesites.org/certified-sites

171. Song, S., et al., 2020 — Exploring integrated design guidelines for urban wetland parks in China. Song, S., Albert, C., & Prominski, M., 2020, Urban Forestry & Urban Greening, 53, 126712

172. Stamm, H., 2003 — Stamm, H., Método para Avaliação de Impacto Ambiental (AIA) em projetos de grande porte: Estudo de caso de uma usina termelétrica.Florianópolis: Tese (Doutorado em Engenharia de Produção) - Programa de Pós-Graduação em Engenharia de Produção, Universidade Federal de Santa Catarina, 2003.

173. Stefanakis, A., et al., 2014 — Vertical Flow Constructed Wetlands: Eco-engineering Systems for Wastewater and Sludge Treatment (1st Ed.) Alexandros I. Stefanakis, Christos S. Akratos, Vassilios A. Tsihrintzis, Amsterdam, The Netherlands: Elsevier Publishing, 2014, https://www.researchgate.net/profile/Alexandros-Stefanakis/publication/288194303_Constructed_Wetlands_Classification/links/5d959edd299bf1c363f2d22c/Constructed-Wetlands-Classification.pdf

174. Stefanakis, A., 2020 — Constructed wetlands for sustainable wastewater treatment in hot and arid climates: opportunities, challenges and case studies in the Middle East, Alexandros I. Stefanakis, Water 12.6, 2020: 1665, DOI: 10.3390/w12061665, https://www.researchgate.net/publication/342095995_Constructed_Wetlands_for_Sustainable_Wastewater_Treatment_in_Hot_and_Arid_Climates_Opportunities_Challenges_and_Case_Studies_in_the_Middle_East

175. Steiner, R., et al., 1989 — Configuration and substrate design considerations for constructed wetlands wastewater treatment, G.R. Steiner, R.J. Freeman, In: HAMMER D.A. (ed.): Constructed wetlands for wastewater treatment, Lewis Publishers, Chelsea, USA, 1989

176. Stockton, G., et al., 2010 — Moriyama and Teshima, Wadi Restoration in Riyadh, George Stockton and Ajon Moriyama, Green Building Festival, Toronto, 2010 https://www.slideshare.net/jeffranson/moriyama-and-teshima-wadi-restoration-in-riyadh-gbf2010

177. Stowell, R., et al., 1985 Mosquito considerations in the design of wetland systems in the treatment of wastewater, R. Stowell, S.Weber, G. Tchobanoglous, B.A. Wilson, K.R. Townzen, In: GODFREY P.J. et al. (eds.): Ecological considerations in wetlands treatment of municipal wastewaters, Van Nostrand Reinhold, New York, 1985

178. Taha, H., 1996 Modeling the Impacts of Increased Urban Vegetation on the Ozone Air Quality in the South Coast Air Basin. Taha, H. 1996. Atmospheric Environment. 30(20): 3423-3430, DOI: 10.1016/1352-2310(96)00035-0, https://eurekamag.com/research/009/030/009030880.php, https://www.sciencedirect.com/science/article/abs/pii/S135223109600336 6?via%3Dihub

179. Taha, H., 1997 Modeling the impacts of large-scale albedo changes on ozone air quality in the South Coast Air Basin. Atmospheric Environment, Haider Taha, 1997, 31(11): 1667-1676. DOI: 10.1016/s1352-2310(96)00336-6, https://eurekamag.com/research/009/031/009031377.php

180. Taha, T., 2009 The Contribution of Greenery to Reducing Pollution, Thabet Taha, Assiut Journal of Environmental Studies - 33rd Issue, Jan. 2009, http://www.aun.edu.eg/arabic/society/pdf/ajoes33_article10.pdf

181. Temesgen, F., et al., 2020 Woody Species Structure and Regeneration Status in Kafta Sheraro National Park Dry Forest, Tigray Region, Ethiopia, Fitsum Temesgen, Bikila Warkineh, International Journal of Forestry Research, vol. 2020, Article ID 4597456, 2020. https://doi.org/10.1155/2020/4597456

182. Tibbetts, J. H, 2015 Air quality and climate change: a delicate balance, J. H. Tibbetts, Environmental Health Perspectives, Vol. 123, No. 6 , 2015, http://dx.doi.org/10.1289/ehp.123-A148 https://ehp.niehs.nih.gov/doi/pdf/10.1289/ehp.123-A148

183. Trottier, J., et al., 2015 Wadi Hanifah Comprehensive Development Plan, Methods Document, Jean Trottier and Kevin Eidick, Landscape Performance Series Case Study Brief, Landscape Architecture Foundation's Case Study Investigation (CSI) program, August 2015, https://www.landscapeperformance.org/sites/default/files/Wadi%20Hanifah%20Methods_0.pdf

184. Turenscape, 2009 Tianjin Qiaoyuan Wetland Park, Turenscape Architects, 2009, Date accessed: 12 August 2021, https://www.turenscape.com/en/project/detail/339.html https://www.turenscape.com/en/project/detail/441.html

185. Turenscape, 2017 Shanghai Houtan Park, Turenscape Architects, 2017, Date accessed: 6 August 2021 https://www.turenscape.com/en/project/detail/4647.html

186. ULI Americas, 2013 Tangshan Nanhu Eco-City Central Park - 2013 Global Awards for Excellence Finalist, Urban Land Institute, ULI Americas, Date accessed: January 25, 2022 https://americas.uli.org/tangshan-nanhu-eco-city-central-park-2013-global-awards-for-excellence/

187. UN, 2015 United Nations. Transforming Our World: The 2030 Agenda for Sustainable Development. 2015.A/RES/70/1. Available online: (accessed on 29/9/2021) https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

188. UN, 2017 United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2017 Revision, Key Findings and Advance Tables, United Nations, Department of Economic and Social Affairs, Population Division, 2017.

189. US EPA, 1992 U.S. EPA. Guidelines for Exposure Assessment, Guidelines for Exposure Assessment, United States Environmental Protection Agency, EPA, 1992, Risk Assessment Forum, Washington, DC, EPA/600/Z-92/001, 1992.https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=15263

190. US EPA, 2021 Using Trees and Vegetation to Reduce Heat Islands, United States Environmental Protection Agency, EPA, 2021, https://www.epa.gov/heatislands/using-trees-and-vegetation-reduce-heat-islands#:~:text=Trees%20and%20vegetation%20lower%20surface,peak%20temperatures%20of%20unshaded%20materials.

191. USGBC, 2022 LEED rating system, Green building leadership is LEED, U.S. Green Building Council, http://www.usgbc.org/

192. Van-Biervliet O., et al., 2020 Can an integrated constructed wetland in Norfolk reduce nutrient concentrations and promote in situ bird species richness?, Olly van Biervliet, Robert J. McInnes, Jonathan Lewis-Phillips & Jonah Tosney, Wetlands volume 40, pages967–981, 2020 DOI: 10.1007/s13157-019-01247-7

193. Vymazal J., 2005 Removal of enteric bacteria in constructed treatment wetlands with emergent macrophytes: A review. Journal of Environmental Science and Health. Part A, Toxic/Hazardous Substances & Environmental Engineering. Jan Vymazal, 2005; 40(6-7): 1355-1367, 10.1081/ESE-200055851 https://www.researchgate.net/publication/7821180_Removal_of_Enteric_Bacteria_in_Constructed_Treatment_Wetlands_with_Emergent_Macrophytes_A_Review

194. Vymazal J., 2010 Constructed Wetlands for Wastewater Treatment, Jan Vymazal, 2010, DOI: 10.3390/w2030530 https://www.researchgate.net/publication/307770338_Constructed_Wetlands_for_Wastewater_Treatment

195. Wee, M., 1999 Wee ML 1999. Predicting urban tree benefits and costs using growth models. Thesis Australian National University Canberra Australia.

196. Wetzel, R., 1993 Constructed wetlands: scientific foundations are critical. R. G. Wetzel, In Constructed Wetlands for Water Quality Improvement, G.-A. Moshiri (ed.). CRC Press, Boca Raton, FL, 1993

197. WHO, 2016 Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease, World Health Organisation, 2016).

198. WHO, 2021 World Health Organization, Ambient (outdoor) air pollution, 2021, Date accessed: 10 January, 2022 https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

199. Wieder, R. et al., 1989 Preliminary considerations regarding constructed wetlands for wastewater treatment, R.K. Wieder, G. Tchobanoglous, R.W. Tuttle, In: HAMMER D.A. (ed.): Constructed wetlands for wastewater treatment, Lewis Publishers, Chelsea, USA, 1989

200. Wong, E. et al., 2012 Cool Pavements, in: Reducing Urban Heat Islands: Compendium of Strategies. Eva Wong, et al., U.S. Environmental Protection Agency. 2012. Draft. Date accessed: 17 November, 2021, https://www.epa.gov/heat-islands/heat-island-compendium

201. World-Architects, 2013 Tianjin Qiaoyuan Park, World-Architects, 2013, Date accessed: 12 August 2021, https://www.world-architects.com/en/turenscape-haidian-district-beijing/project/tianjin-qiaoyuan-park

202. World-Architects, 2017 Shanghai Houtan Park, World-Architects, Date accessed: 6 August 2021, https://www.world-architects.com/en/turenscape-haidian-district-beijing/project/shanghai-houtan-park

203. Wu, H., et al., 2015 A review on the sustainability of constructed wetlands for wastewater treatment: Design and operation, Haiming Wu, Jian Zhang, Huu Hao Ngo, Wenshan Guo, Zhen Hu, Shuang Liang, Jinlin Fan, Hai Liu, Bioresour Technol, 2015. https://doi.org/10.1016/j.biortech.2014.10.068

204. Yang, W. et al., 2008 Ecosystem service value assessment for constructed wetlands: A case study in Hangzhou, Wu Yang, Jie Chang, Bin Xu, Changhui Peng, Ying Ge, China, Ecological Economics 68, 2008, pp.116–125, DOI:10.1016/j.ecolecon.2008.02.008, https://www.researchgate.net/publication/222542267_Ecosystem_service_value_assessment_for_constructed_wetlands_A_case_study_in_Hangzhou_China

205. Yang, Y., et al., 2016 The Impact of Social Group Behaviors on Landscape, Performance: A Case Study of Four Chinese Urban Park, Yang Yang, Guangsi Lin, Honghong Zhao, Landscape Research Record N5, 2016, 73-87, https://www.researchgate.net/publication/338986773_The_Impact_of_Social_Group_Behaviors_on_Landscape_Performance_A_Case_Study_of_Four_Chinese_Urban_Park

206. Zakaria, Y. et al., 2021 Sustainability Assessment for Wastewater Treatment Systems—Case Studies in Egypt, Yousra M. Zakaria, Ahmed El Gendy, and Salah El Haggar, 2021, *Journal of Environmental Protection*, *12, 90-105,* DOI: 10.4236/jep.2021.122007 102, [accessed Sep 29, 2021]. https://www.researchgate.net/publication/349500298_Sustainability_Assessment_for_Wastewater_Treatment_Systems-Case_Studies_in_Egypt

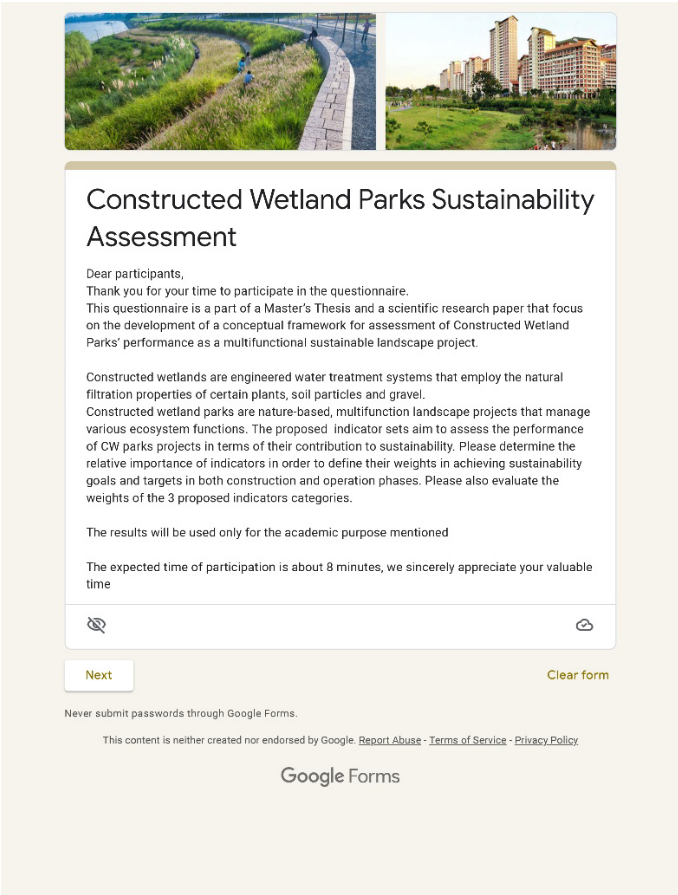
207. Zhang, D. et al.,2009 Constructed wetlands in China, Zhang D., Gersberg R. M., Kea T. S., Ecological Engineering 35, 2009 pp.1367–1378

208. Zirkle et al. 2012 Modeling Carbon Sequestration in the U.S. Residential Landscape. Gina Zirkle, Lal Rattan, Augustin Bruce, Follett R. In: Lal R., Augustin B. (Eds), Carbon Sequestration in Urban Ecosystems. Springer, 2012, pp. 265–276.

209. Zofnass, 2016 Proposition O, South Los Angeles Wetland Park, 54th And Avalon, Los Angeles, Ca, Evgenia Chatzistavrou, Zofnass Program for Sustainable Infrastructure, 2016, Date accessed: 7 February 2022 https://research.gsd.harvard.edu/zofnass/files/2020/05/2_ENVISION-RATED-PROJECTS_South-LA-Wetland-Park_final.pdf

210. Site reference www.bslanow.org, asu_bsla-2019__page_19
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

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

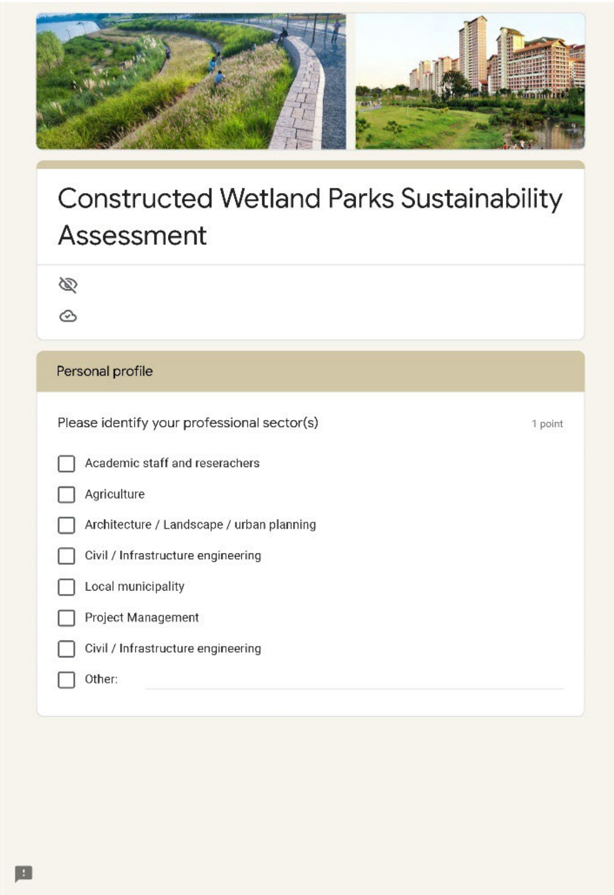
The expected time of participation is about 8 minutes, we sincerely appreciate your valuable time

Next | Clear form

Never submit passwords through Google Forms.

This content is neither created nor endorsed by Google. Report Abuse - Terms of Service - Privacy Policy

Google Forms

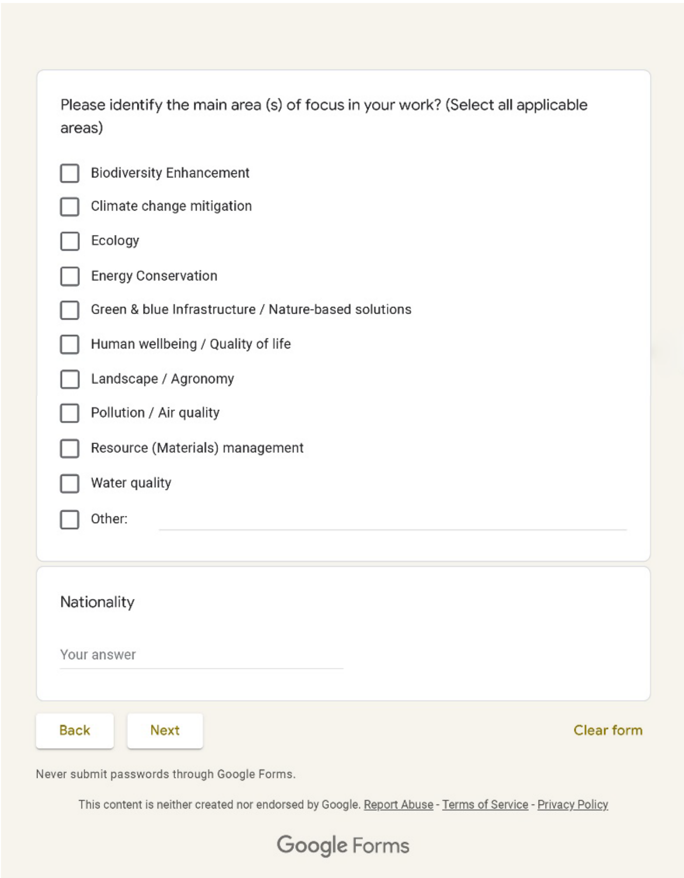


Constructed Wetland Parks Sustainability Assessment

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

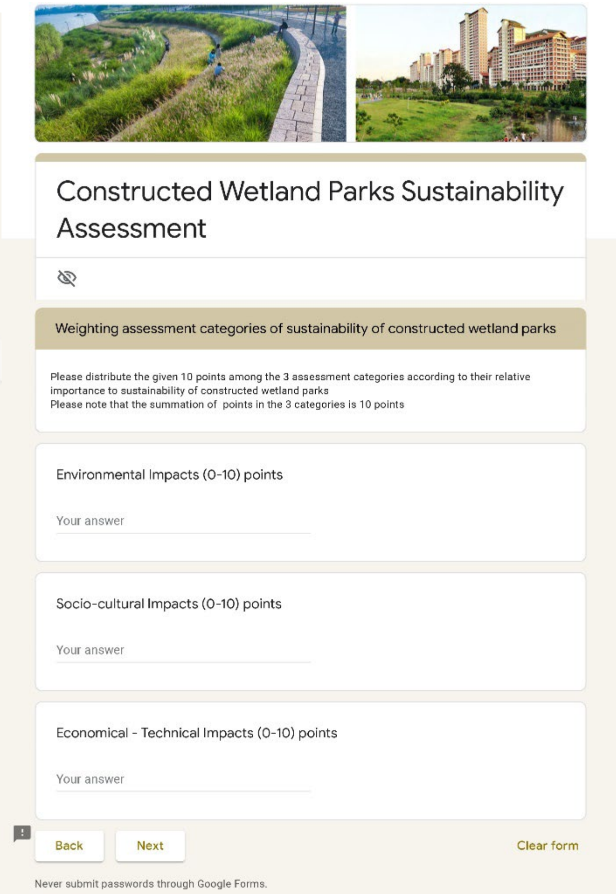
Your answer

Back | Next | Clear form

Never submit passwords through Google Forms.

This content is neither created nor endorsed by Google. Report Abuse - Terms of Service - Privacy Policy

Google Forms



Constructed Wetland Parks Sustainability Assessment

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

Back | Next | Clear form

Never submit passwords through Google Forms.

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

Back Next Clear form

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

Back Next Clear form

Never submit passwords through Google Forms.

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

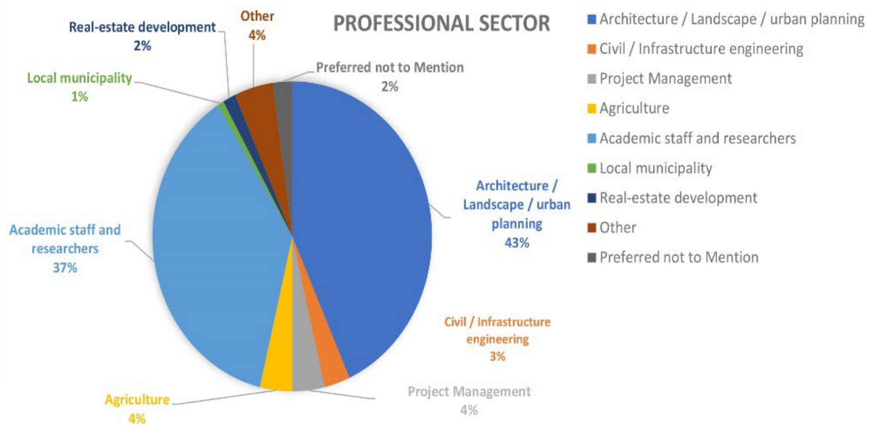
Least important 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Most important

Back Submit Clear form

Appendix (2) Analysis of question results

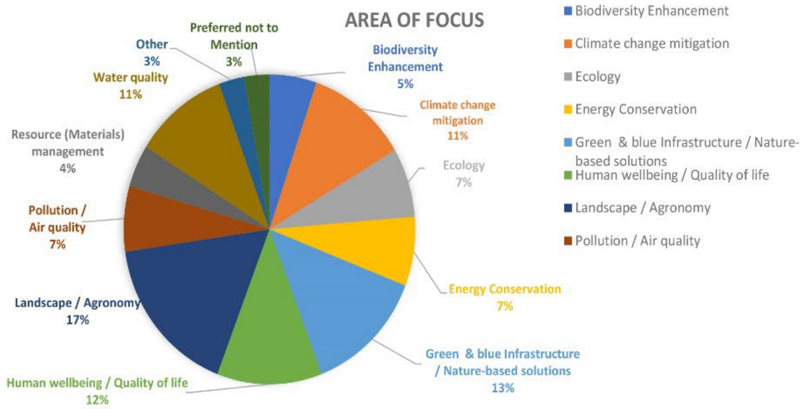
First Section: *Participant's Profile:*

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%



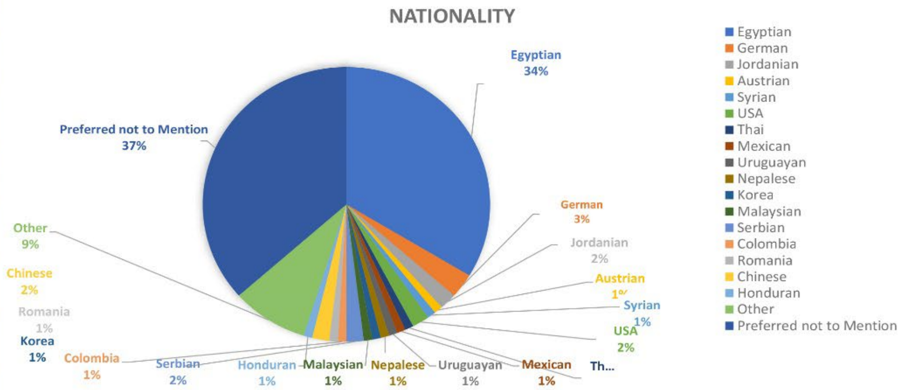
Q1_Please identify your professional sector(s)

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)

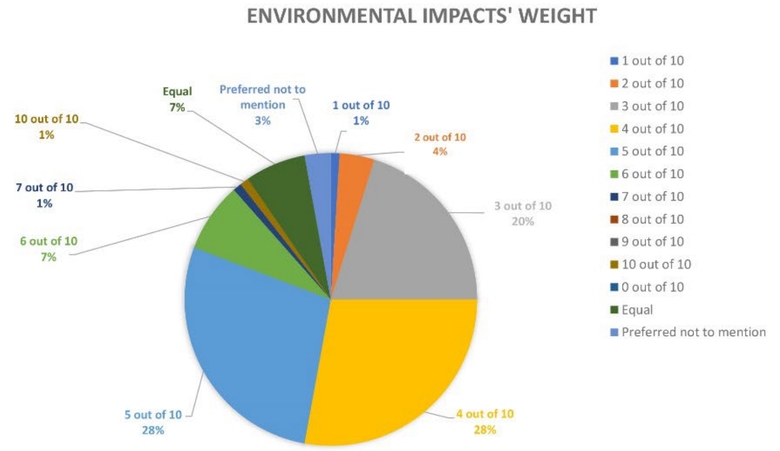
Q3_Nationality	Respondents	Percent
Egyptian	35	33.65%
German	3	2.88%
Jordanian	2	1.92%
Austrian	1	0.96%
Syrian	1	0.96%
USA	2	1.92%
Thai	1	0.96%
Mexican	1	0.96%
Uruguayan	1	0.96%
Nepalese	1	0.96%
Korea	1	0.96%
Malaysian	1	0.96%
Serbian	2	1.92%
Colombia	1	0.96%
Romania	1	0.96%
Chinese	2	1.92%
Honduran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



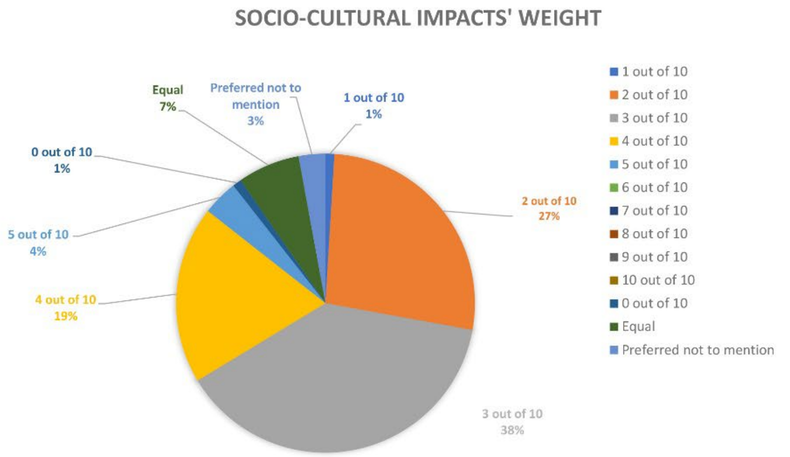
Q3_Nationality

Second Section: *Determination of the weights for the main categories of CW Parks sustainability assessment*

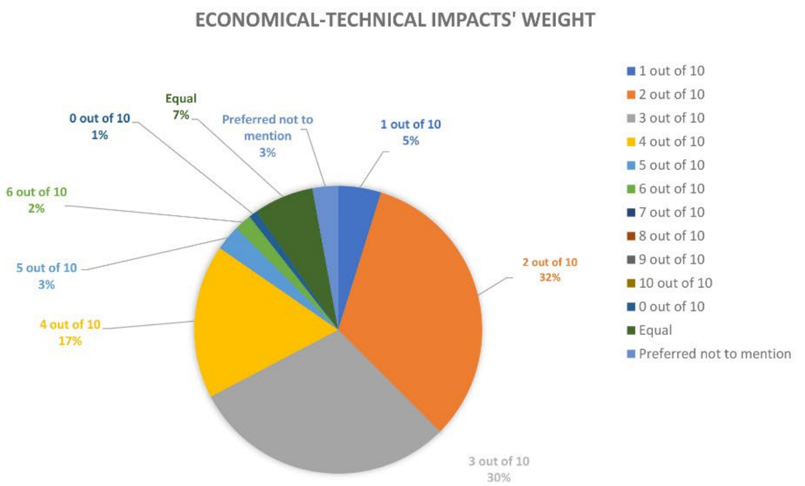
Q4_Environmental Impacts (0-10) points	Respondents	Percent	Score
1 out of 10	1	0.96%	0.1
2 out of 10	4	3.85%	0.2
3 out of 10	21	20.19%	0.3
4 out of 10	29	27.88%	0.4
5 out of 10	29	27.88%	0.5
6 out of 10	8	7.69%	0.6
7 out of 10	1	0.96%	0.7
8 out of 10	0	0%	0.8
9 out of 10	0	0%	0.9
10 out of 10	1	0.01	**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
	39.8	42.34%	94
WAI = $\frac{\sum fi\, wi}{\sum fi}$	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
	27.7	29.47%	94
WAI = $\frac{\sum fi\, wi}{\sum fi}$	94	29.47%	0.294681



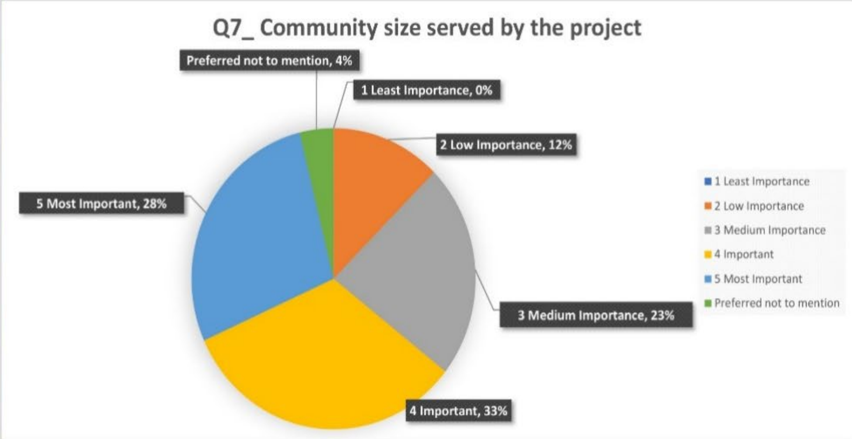
Q6_Economical - Technical Impacts (0-10) points	Respondents	Percent	Score
1 out of 10	5	4.81%	0.1
2 out of 10	34	32.69%	0.2
3 out of 10	31	29.81%	0.3
4 out of 10	18	17.31%	0.4
5 out of 10	3	2.88%	0.5
6 out of 10	2	1.92%	0.6
7 out of 10	0	0.00%	0.7
8 out of 10	0	0%	0.8
9 out of 10	0	0.00%	0.9
10 out of 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
	26.5	28.19%	94
WAI = $\frac{\sum fi\, wi}{\sum fi}$	94	28.19%	0.281915



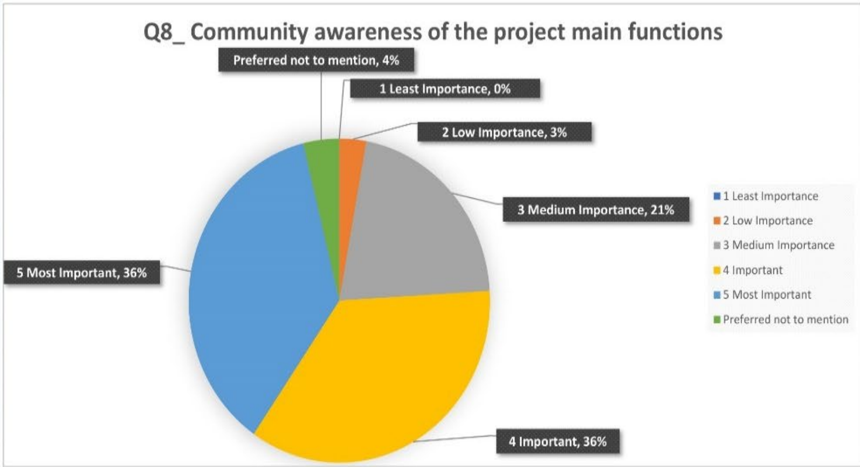
Third Section: *Individual Indicator Weights identification*

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

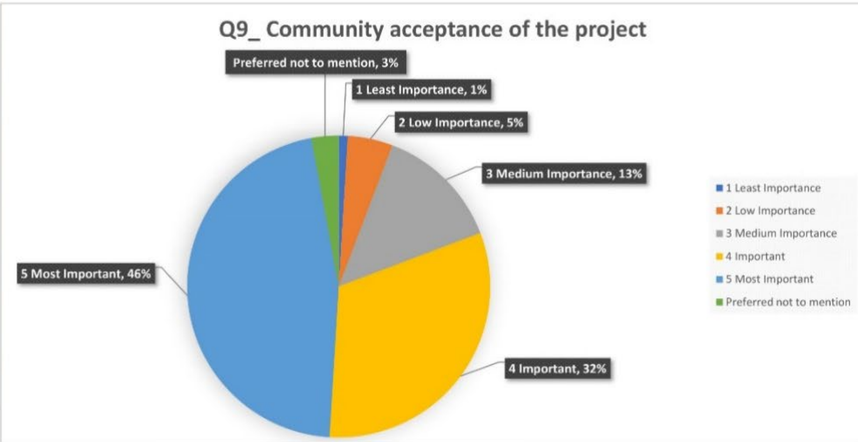
Q7_ Community size served by the project	Respondents	Percent	Score
1 Least Importance	0	0.00%	0.2
2 Low Importance	13	12.50%	0.4
3 Medium Importance	24	23.08%	0.6
4 Important	34	32.69%	0.8
5 Most Important	29	27.88%	1
Preferred not to mention	4	3.85%	
Total	104	100%	75.8
	75.8	75.80%	100
WAI = $\frac{\sum fi\ wi}{\sum fi}$	100	0.76	**0.8**



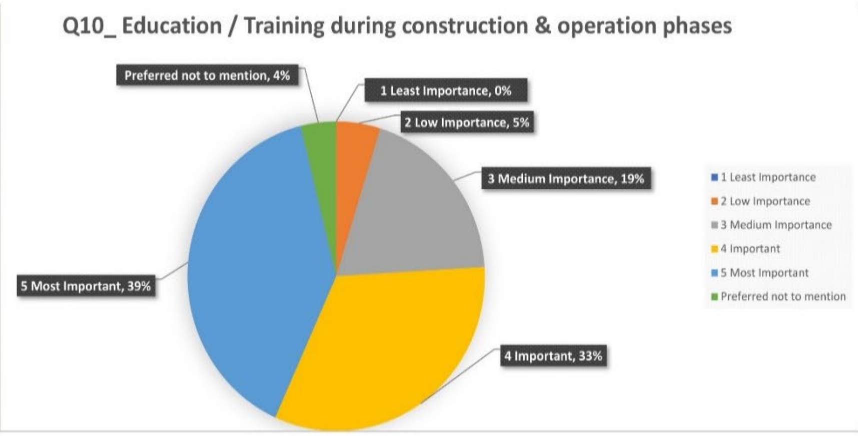
Q8_ Community awareness of the project main functions	Respondents	Percent	Score
1 Least Importance	0	**0.00%**	0.2
2 Low Importance	3	**2.88%**	0.4
3 Medium Importance	22	**21.15%**	0.6
4 Important	37	**35.58%**	0.8
5 Most Important	38	**36.54%**	1
Preferred not to mention	4	**3.85%**	
Total	104	**100%**	82
	82	**82.00%**	100
WAI = $\frac{\sum fi\ wi}{\sum fi}$	100	**0.82**	**0.8**



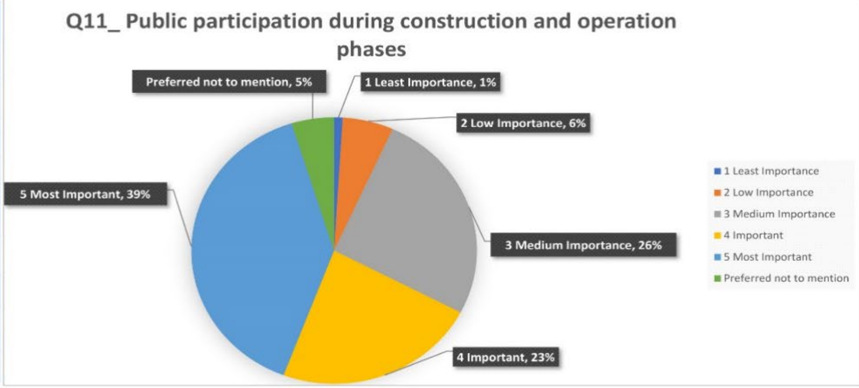
Q9_ Community acceptance of the project	Respondents	Percent	Score
1 Least Importance	1	0.96%	0.2
2 Low Importance	5	4.81%	0.4
3 Medium Importance	14	13.46%	0.6
4 Important	33	31.73%	0.8
5 Most Important	48	46.15%	1
Preferred not to mention	3	2.88%	
Total	104	100%	85
	85	84.16%	101
WAI = $\frac{\sum fi\ wi}{\sum fi}$	101	0.84	**0.8**



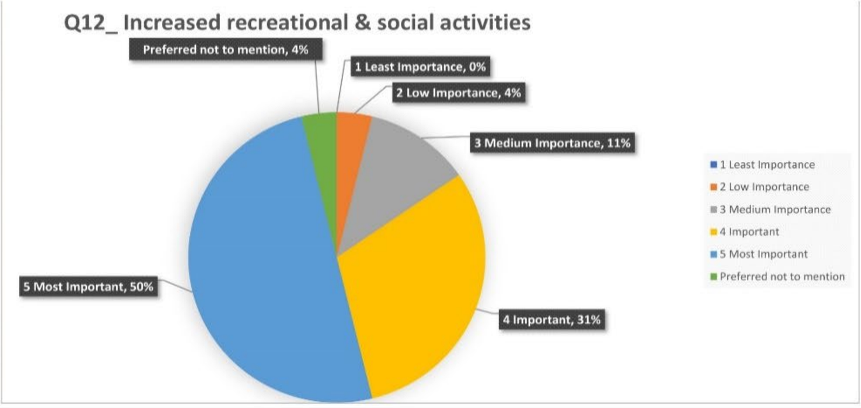
Q10_ Education / Training during construction & operation phases	Respondents	Percent	Score
1 Least Importance	0	0.00%	0.2
2 Low Importance	5	4.81%	0.4
3 Medium Importance	20	19.23%	0.6
4 Important	34	32.69%	0.8
5 Most Important	41	39.42%	1
Preferred not to mention	4	3.85%	
Total	104	100%	82.2
	82.2	82.20%	100
WAI = $\frac{\sum fi\ wi}{\sum fi}$	100	0.82	**0.8**



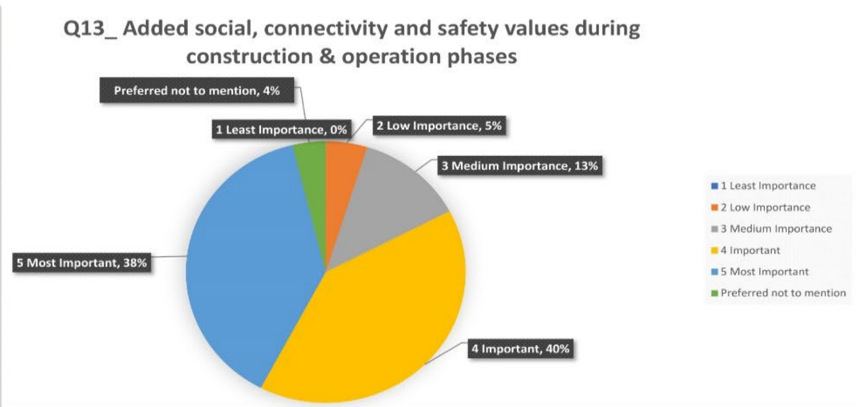
Q11_ Public participation during construction and operation phases	Respondents	Percent	Score
1 Least Importance	1	0.96%	0.2
2 Low Importance	6	5.77%	0.4
3 Medium Importance	27	25.96%	0.6
4 Important	24	23.08%	0.8
5 Most Important	41	39.42%	1
Preferred not to mention	5	4.81%	
Total	104	100%	79
	79	79.80%	99
WAI = $\frac{\sum fi\, wi}{\sum fi}$	99	0.80	**0.8**



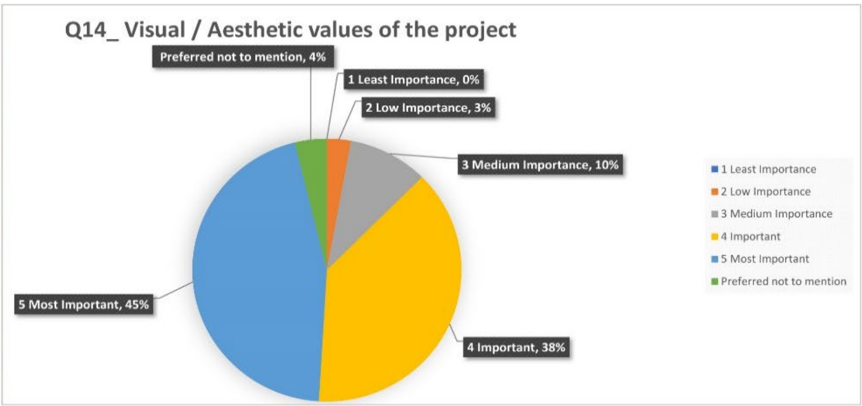
Q12_ Increased recreational & social activities	Respondents	Percent	Score
1 Least Importance	0	0.00%	0.2
2 Low Importance	4	3.85%	0.4
3 Medium Importance	12	11.54%	0.6
4 Important	32	30.77%	0.8
5 Most Important	52	50.00%	1
Preferred not to mention	4	3.85%	
Total	104	100%	86.4
	86.4	86.40%	100
WAI = $\frac{\sum fi\, wi}{\sum fi}$	100	0.86	**0.9**



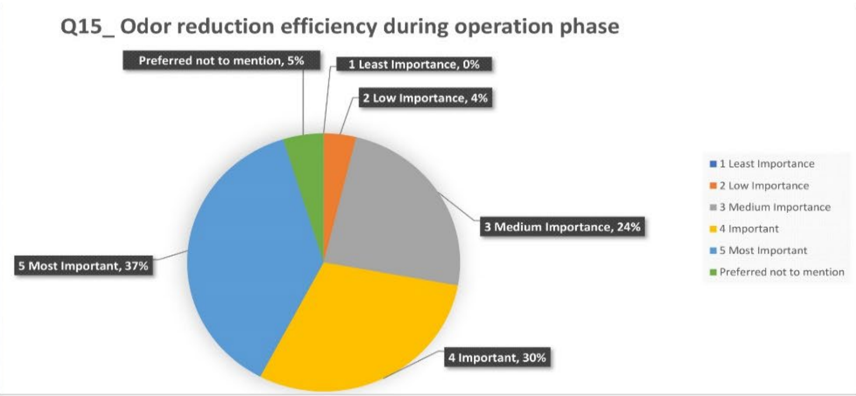
Q13_ Added social, connectivity and safety values during construction & operation phases	Respondents	Percent	Score
1 Least Importance	0	0.00%	0.2
2 Low Importance	5	4.81%	0.4
3 Medium Importance	13	12.50%	0.6
4 Important	42	40.38%	0.8
5 Most Important	40	38.46%	1
Preferred not to mention	4	3.85%	
Total	104	100%	83.4
	83.4	83.40%	100
WAI = $\frac{\sum fi\, wi}{\sum fi}$	100	0.83	**0.8**



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
	86.2	86.20%	100
WAI = $\frac{\sum fi\, wi}{\sum fi}$	100	0.86	**0.9**

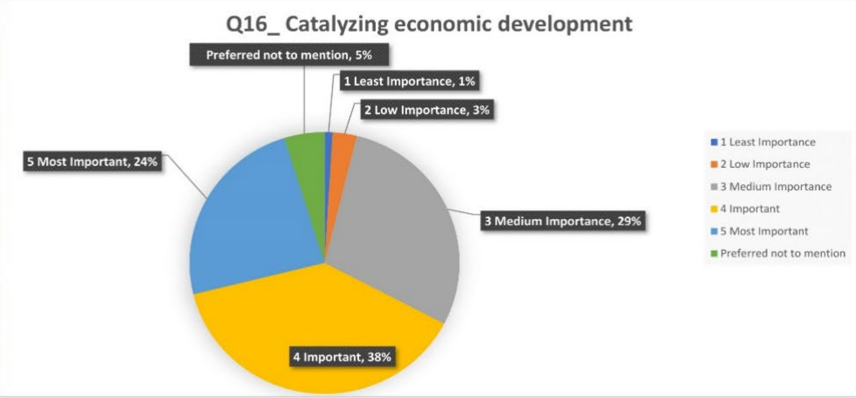


Q15_ Odor reduction efficiency during operation phase	Respondents	Percent	Score
1 Least Importance	0	0.00%	0.2
2 Low Importance	4	3.85%	0.4
3 Medium Importance	25	24.04%	0.6
4 Important	31	29.81%	0.8
5 Most Important	39	37.50%	1
Preferred not to mention	5	4.81%	
Total	104	100%	80.4
	80.4	81.21%	99
WAI = $\frac{\sum fi\, wi}{\sum fi}$	99	0.81	**0.8**

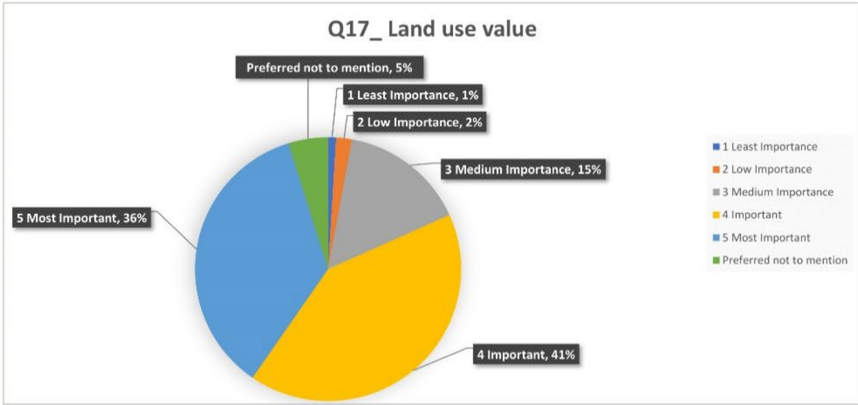


Part 2: Weighting Economic - Technical indicators of constructed wetland parks:

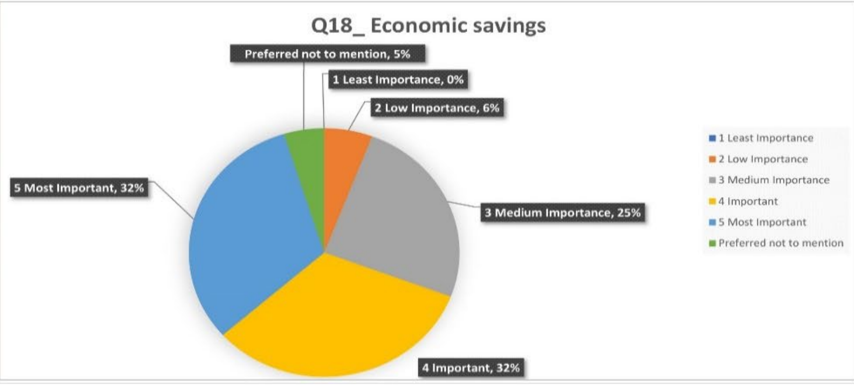
Q16_ Catalyzing economic development	Respondents	Percent	Score
1 Least Importance	1	0.96%	0.2
2 Low Importance	3	2.88%	0.4
3 Medium Importance	30	28.85%	0.6
4 Important	40	38.46%	0.8
5 Most Important	25	24.04%	1
Preferred not to mention	5	4.81%	
Total	104	100%	76.4
	76.4	77.17%	99
WAI = $\frac{\sum fi\,wi}{\sum fi}$	99	0.77	**0.8**



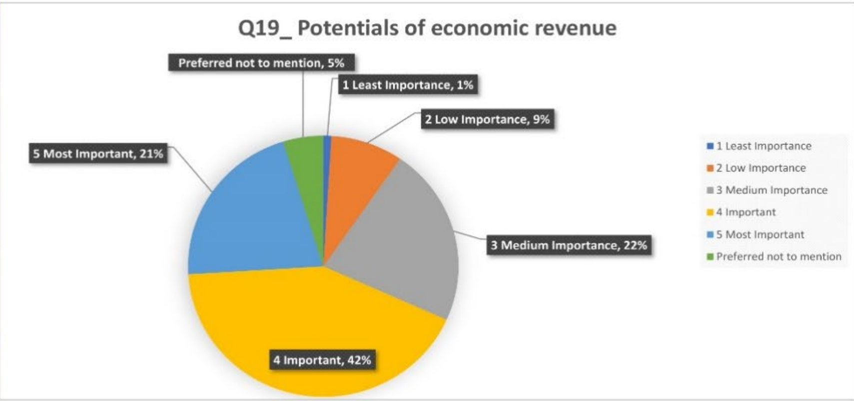
Q17_ Land use value	Respondents	Percent	Score
1 Least Importance	1	0.96%	0.2
2 Low Importance	2	1.92%	0.4
3 Medium Importance	16	15.38%	0.6
4 Important	43	41.35%	0.8
5 Most Important	37	35.58%	1
Preferred not to mention	5	4.81%	
Total	104	100%	82
	82	82.83%	99
WAI = $\frac{\sum fi\,wi}{\sum fi}$	99	0.83	**0.8**



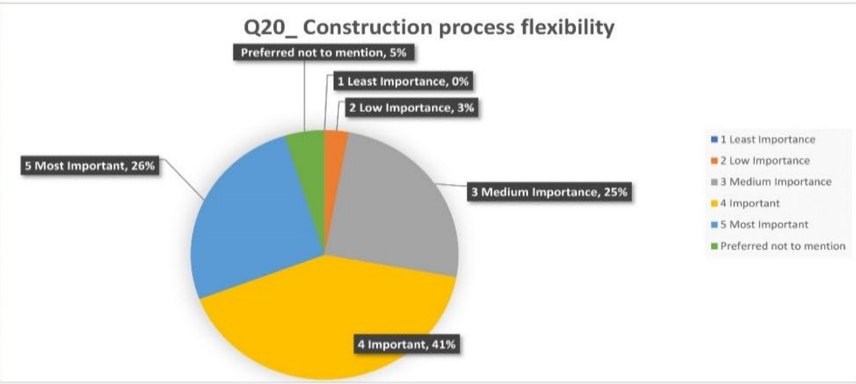
Q18_ Economic savings	Respondents	Percent	Score
1 Least Importance	0	0.00%	0.2
2 Low Importance	6	5.77%	0.4
3 Medium Importance	26	25.00%	0.6
4 Important	34	32.69%	0.8
5 Most Important	33	31.73%	1
Preferred not to mention	5	4.81%	
Total	104	100%	78.2
	78.2	78.99%	99
WAI = $\frac{\sum fi\,wi}{\sum fi}$	99	0.79	**0.8**



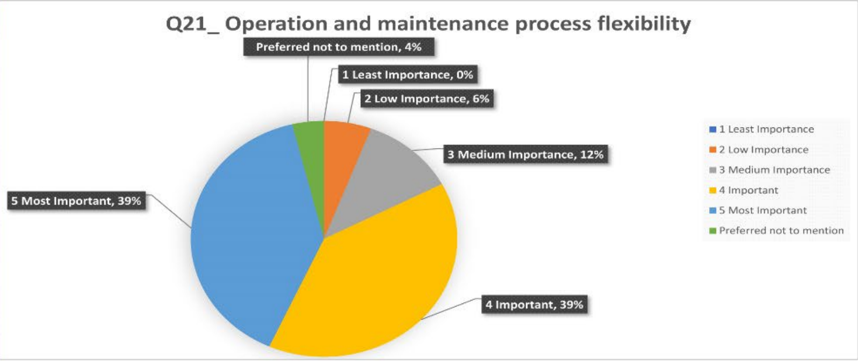
Q19_ Potentials of economic revenue	Respondents	Percent	Score
1 Least Importance	1	0.96%	0.2
2 Low Importance	9	8.65%	0.4
3 Medium Importance	23	22.12%	0.6
4 Important	44	42.31%	0.8
5 Most Important	22	21.15%	1
Preferred not to mention	5	4.81%	
Total	104	100%	74.8
	74.8	75.56%	99
WAI = $\frac{\sum fi\,wi}{\sum fi}$	99	0.76	**0.8**



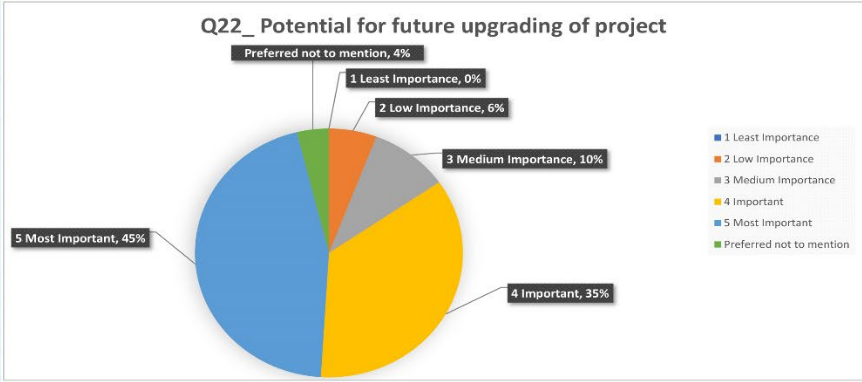
Q20_ Construction process flexibility	Respondents	Percent	Score
1 Least Importance	0	0.00%	0.2
2 Low Importance	3	2.88%	0.4
3 Medium Importance	26	25.00%	0.6
4 Important	43	41.35%	0.8
5 Most Important	27	25.96%	1
Preferred not to mention	5	4.81%	
Total	104	100%	78.2
	78.2	78.99%	99
WAI = $\frac{\sum fi\,wi}{\sum fi}$	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 = $\frac{\sum fi\ wi}{\sum fi}$	100	0.83	0.8

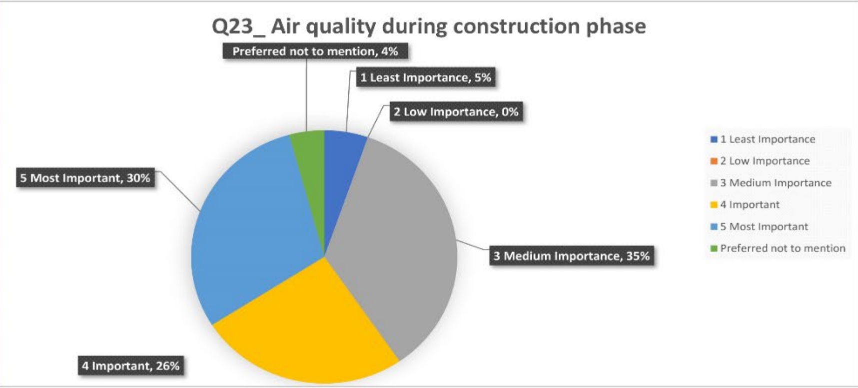


Q22_ Potential for future upgrading of project	Respondents	Percent	Score
1 Least Importance	0	0.00%	0.2
2 Low Importance	6	5.77%	0.4
3 Medium Importance	10	9.62%	0.6
4 Important	37	35.58%	0.8
5 Most Important	47	45.19%	1
Preferred not to mention	4	3.85%	
Total	104	100%	85
	85	85.00%	100
WAI = $\frac{\sum fi\ wi}{\sum fi}$	100	0.85	0.9

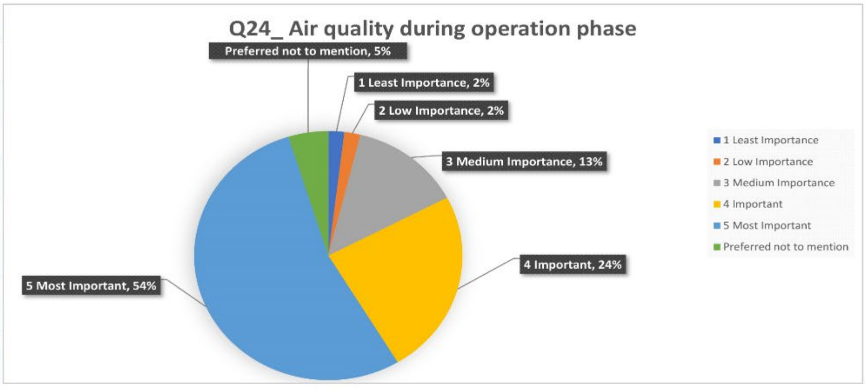


Part 3: Weighting Environmental indicators of constructed wetland parks:

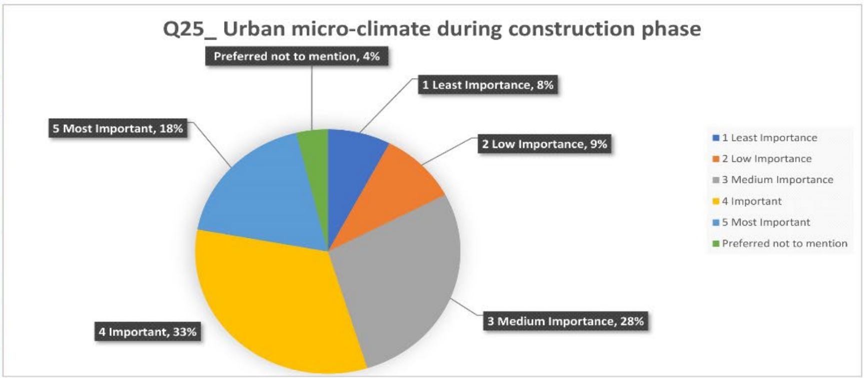
Q23_ Air quality during construction phase	Respondents	Percent	Score
1 Least Importance	5	5.32%	0.2
2 Low Importance	0	0.00%	0.4
3 Medium Importance	33	35.11%	0.6
4 Important	24	25.53%	0.8
5 Most Important	28	29.79%	1
Preferred not to mention	4	4.26%	
Total	94	100%	68
	68	75.56%	90
WAI = $\frac{\sum fi\ wi}{\sum fi}$	90	0.76	0.8



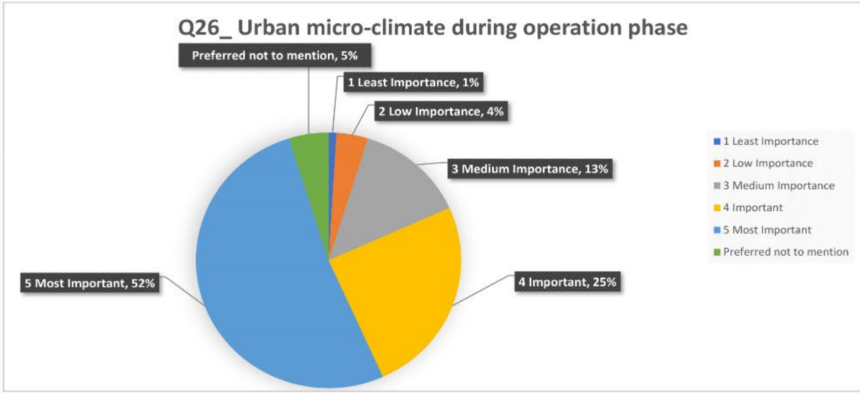
Q24_ Air quality during operation phase	Respondents	Percent	Score
1 Least Importance	2	1.92%	0.2
2 Low Importance	2	1.92%	0.4
3 Medium Importance	14	13.46%	0.6
4 Important	25	24.04%	0.8
5 Most Important	56	53.85%	1
Preferred not to mention	5	4.81%	
Total	104	100%	85.6
	85.6	86.46%	99
WAI = $\frac{\sum fi\ wi}{\sum fi}$	99	0.86	0.9



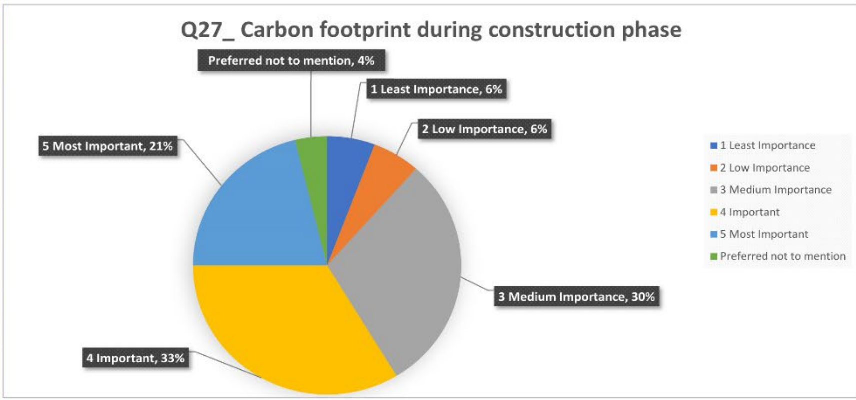
Q25_ Urban micro-climate during construction phase	Respondents	Percent	Score
1 Least Importance	8	7.69%	0.2
2 Low Importance	10	9.62%	0.4
3 Medium Importance	29	27.88%	0.6
4 Important	34	32.69%	0.8
5 Most Important	19	18.27%	1
Preferred not to mention	4	3.85%	
Total	104	100%	69.2
	69.2	69.20%	100
WAI = $\frac{\sum fi\ wi}{\sum fi}$	100	0.69	0.7



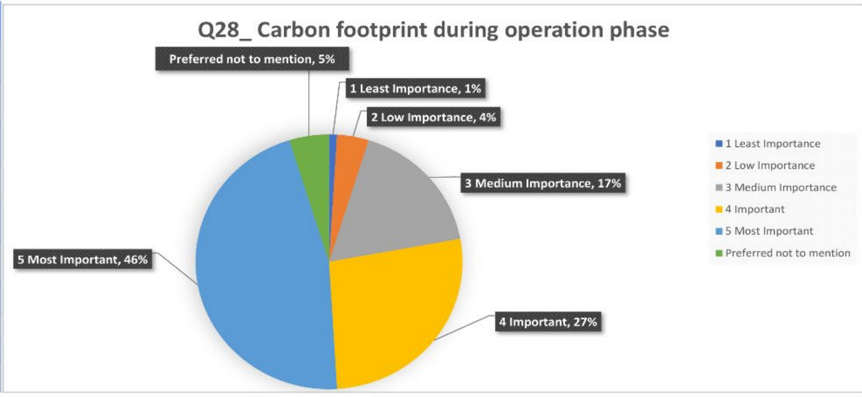
Q26_ Urban micro-climate during operation phase	Respondents	Percent	Score
1 Least Importance	1	0.96%	0.2
2 Low Importance	4	3.85%	0.4
3 Medium Importance	14	13.46%	0.6
4 Important	26	25.00%	0.8
5 Most Important	54	51.92%	1
Preferred not to mention	5	4.81%	
Total	104	100%	85
	85	85.86%	99
WAI = $\frac{\sum fi\, wi}{\sum fi}$	99	0.86	**0.9**



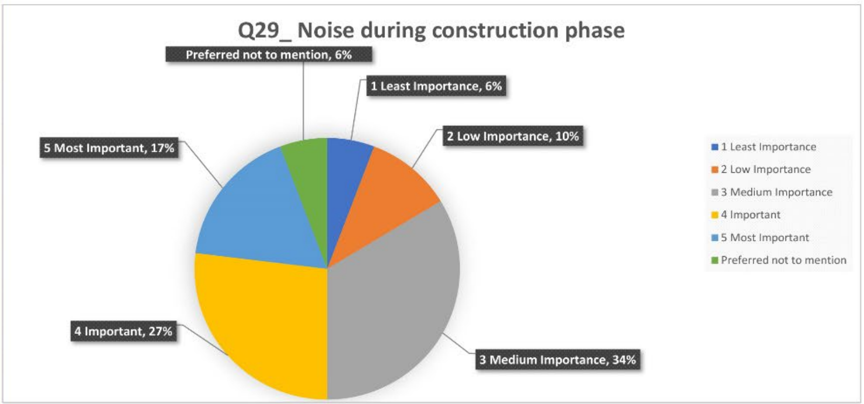
Q27_ Carbon footprint during construction phase	Respondents	Percent	Score
1 Least Importance	6	5.77%	0.2
2 Low Importance	6	5.77%	0.4
3 Medium Importance	31	29.81%	0.6
4 Important	35	33.65%	0.8
5 Most Important	22	21.15%	1
Preferred not to mention	4	3.85%	
Total	104	100%	72.2
	72.2	72.20%	100
WAI = $\frac{\sum fi\, wi}{\sum fi}$	100	0.72	**0.7**



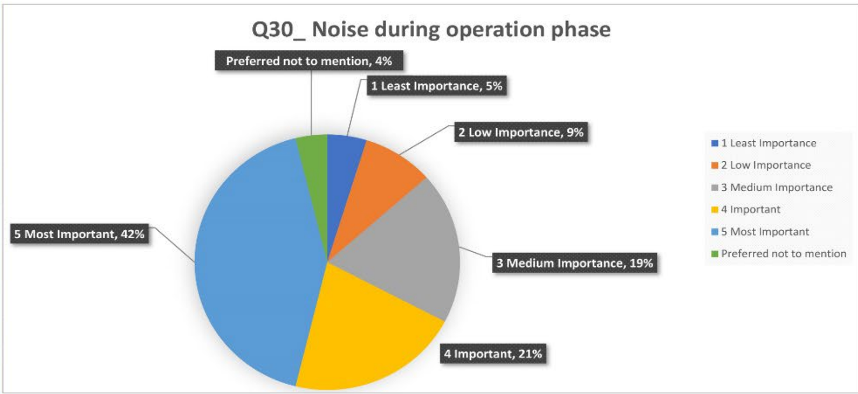
Q28_ Carbon footprint during operation phase	Respondents	Percent	Score
1 Least Importance	1	0.96%	0.2
2 Low Importance	4	3.85%	0.4
3 Medium Importance	18	17.31%	0.6
4 Important	28	26.92%	0.8
5 Most Important	48	46.15%	1
Preferred not to mention	5	4.81%	
Total	104	100%	83
	83	83.84%	99
WAI = $\frac{\sum fi\, wi}{\sum fi}$	99	0.84	**0.8**



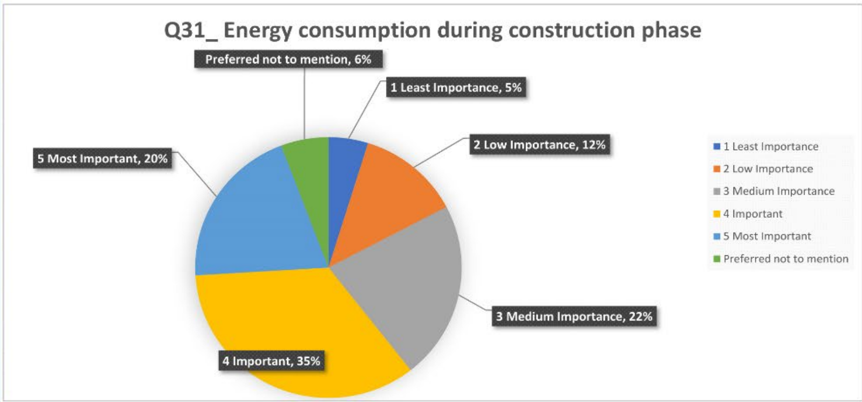
Q29_ Noise during construction phase	Respondents	Percent	Score
1 Least Importance	6	5.77%	0.2
2 Low Importance	11	10.58%	0.4
3 Medium Importance	35	33.65%	0.6
4 Important	28	26.92%	0.8
5 Most Important	18	17.31%	1
Preferred not to mention	6	5.77%	
Total	104	100%	67
	67	68.37%	98
WAI = $\frac{\sum fi\, wi}{\sum fi}$	98	0.68	**0.7**



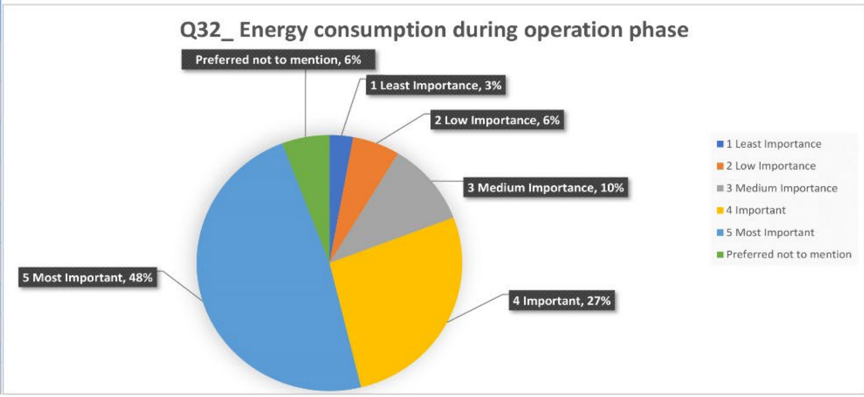
Q30_ Noise during operation phase	Respondents	Percent	Score
1 Least Importance	5	4.81%	0.2
2 Low Importance	9	8.65%	0.4
3 Medium Importance	20	19.23%	0.6
4 Important	22	21.15%	0.8
5 Most Important	44	42.31%	1
Preferred not to mention	4	3.85%	
Total	104	100%	78.2
	78.2	78.20%	100
WAI = $\frac{\sum fi\, wi}{\sum fi}$	100	0.78	**0.8**



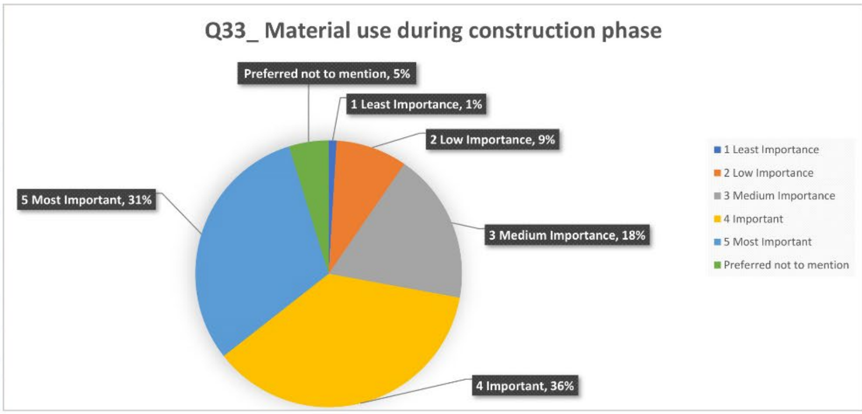
Q31_ Energy consumption during construction phase	Respondents	Percent	Score
1 Least Importance	5	4.81%	0.2
2 Low Importance	13	12.50%	0.4
3 Medium Importance	23	22.12%	0.6
4 Important	36	34.62%	0.8
5 Most Important	21	20.19%	1
Preferred not to mention	6	5.77%	
Total	104	100%	69.8
	69.8	71.22%	98
WAI = $\frac{\sum fi\ wi}{\sum fi}$	98	0.71	**0.7**



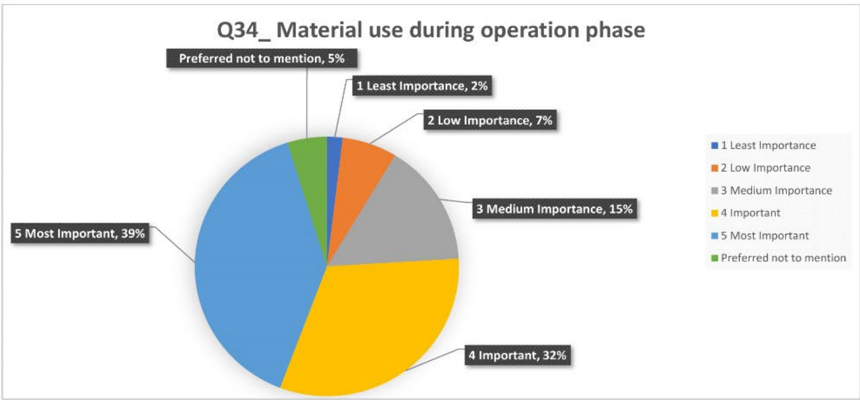
Q32_ Energy consumption during operation phase	Respondents	Percent	Score
1 Least Importance	3	2.88%	0.2
2 Low Importance	6	5.77%	0.4
3 Medium Importance	11	10.58%	0.6
4 Important	28	26.92%	0.8
5 Most Important	50	48.08%	1
Preferred not to mention	6	5.77%	
Total	104	100%	82
	82	83.67%	98
WAI = $\frac{\sum fi\ wi}{\sum fi}$	98	0.84	**0.8**



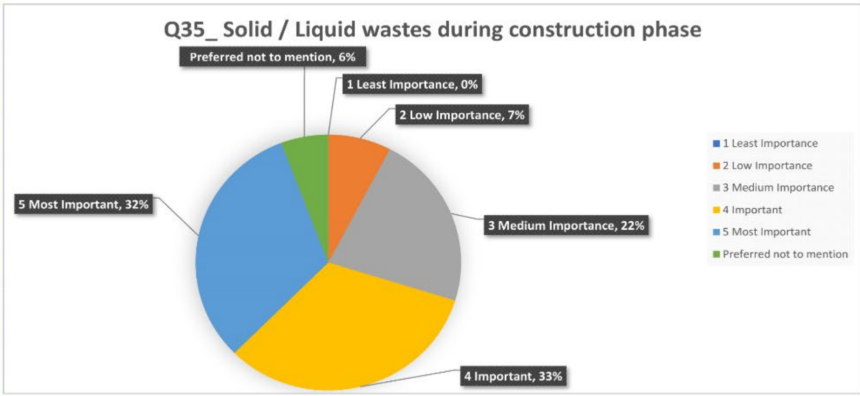
Q33_ Material use during construction phase	Respondents	Percent	Score
1 Least Importance	1	0.96%	0.2
2 Low Importance	9	8.65%	0.4
3 Medium Importance	19	18.27%	0.6
4 Important	38	36.54%	0.8
5 Most Important	32	30.77%	1
Preferred not to mention	5	4.81%	
Total	104	100%	77.6
	77.6	78.38%	99
WAI = $\frac{\sum fi\ wi}{\sum fi}$	99	0.78	**0.8**



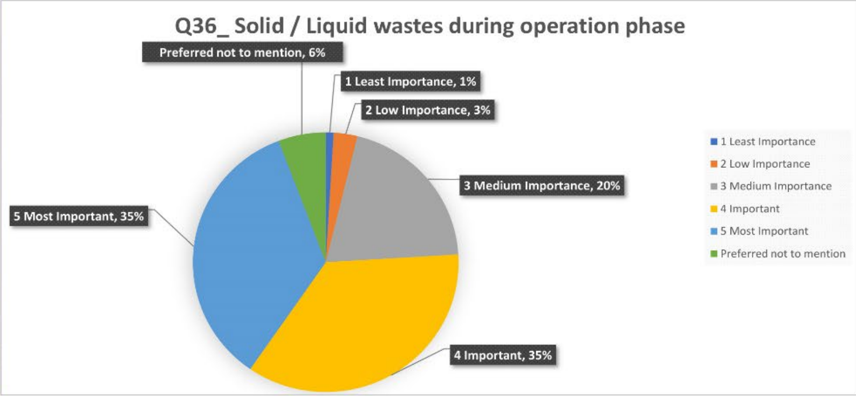
Q34_ Material use during operation phase	Respondents	Percent	Score
1 Least Importance	2	1.92%	0.2
2 Low Importance	7	6.73%	0.4
3 Medium Importance	16	15.38%	0.6
4 Important	33	31.73%	0.8
5 Most Important	41	39.42%	1
Preferred not to mention	5	4.81%	
Total	104	100%	80.2
	80.2	81.01%	99
WAI = $\frac{\sum fi\ wi}{\sum fi}$	99	0.81	**0.8**



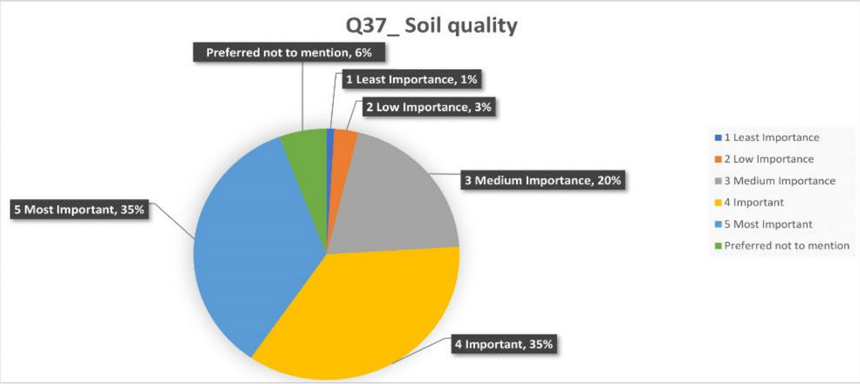
Q35_ Solid / Liquid wastes during construction phase	Respondents	Percent	Score
1 Least Importance	0	0.00%	0.2
2 Low Importance	8	7.69%	0.4
3 Medium Importance	23	22.12%	0.6
4 Important	34	32.69%	0.8
5 Most Important	33	31.73%	1
Preferred not to mention	6	5.77%	
Total	104	100%	77.2
	77.2	78.78%	98
WAI = $\frac{\sum fi\ wi}{\sum fi}$	98	0.79	**0.8**



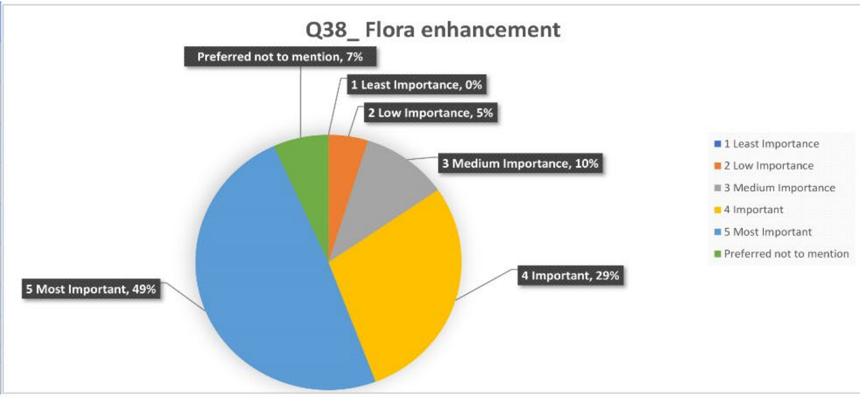
Q36_ Solid / Liquid wastes during operation phase	Respondents	Percent	Score
1 Least Importance	1	0.96%	0.2
2 Low Importance	3	2.88%	0.4
3 Medium Importance	21	20.19%	0.6
4 Important	37	35.58%	0.8
5 Most Important	36	34.62%	1
Preferred not to mention	6	5.77%	
Total	104	100%	79.6
	79.6	81.22%	98
WAI = $\frac{\sum fi\ wi}{\sum fi}$	98	0.81	**0.8**



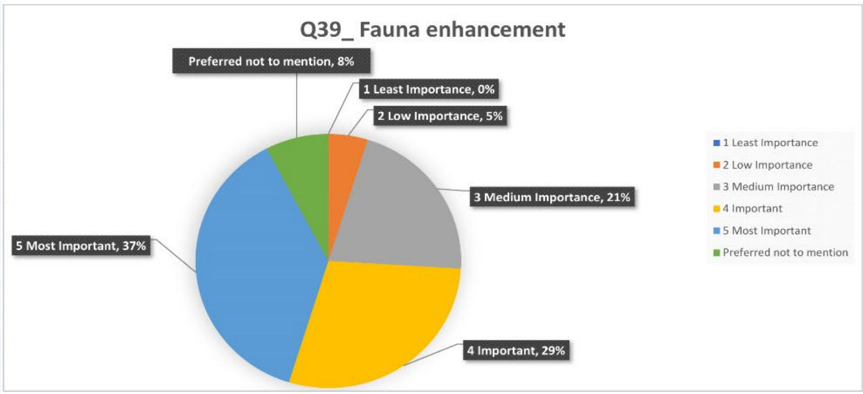
Q37_ Soil quality	Respondents	Percent	Score
1 Least Importance	1	0.96%	0.2
2 Low Importance	3	2.88%	0.4
3 Medium Importance	21	20.19%	0.6
4 Important	37	35.58%	0.8
5 Most Important	36	34.62%	1
Preferred not to mention	6	5.77%	
Total	104	100%	79.6
	79.6	81.22%	98
WAI = $\frac{\sum fi\ wi}{\sum fi}$	98	0.81	**0.8**



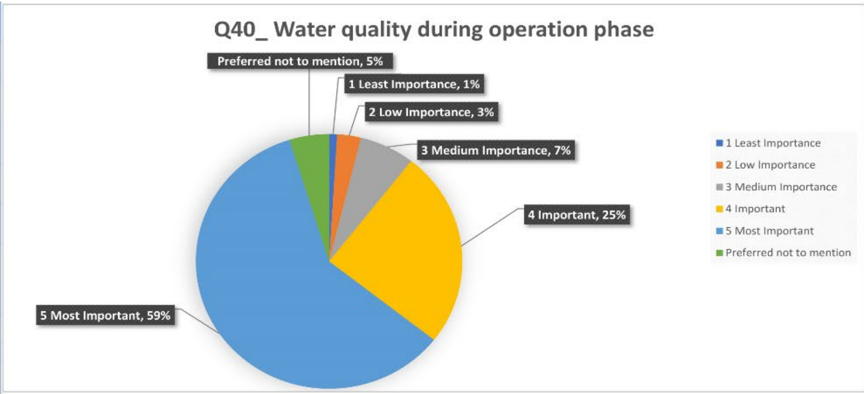
Q38_ Flora enhancement	Respondents	Percent	Score
1 Least Importance	0	0.00%	0.2
2 Low Importance	5	4.81%	0.4
3 Medium Importance	11	10.58%	0.6
4 Important	30	28.85%	0.8
5 Most Important	51	49.04%	1
Preferred not to mention	7	6.73%	
Total	104	100%	83.6
	83.6	86.19%	97
WAI = $\frac{\sum fi\ wi}{\sum fi}$	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 = $\frac{\sum fi\ wi}{\sum fi}$	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 = $\frac{\sum fi\ wi}{\sum fi}$	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	Vachellia 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	Aizoanthemopsis Klak	105	Asphodelus L.	205	Coldenia L.	305	Cleome L.	405	Frankenia L.	505	Nanorrhinum Betsche	605	Triraphis R.Br.
6	Aizoon L.	106	Achillea L.	206	Cordia L.	306	Colchicum L.	406	Centaurium Hill	506	Plantago L.	606	Trisetaria Forssk.
7	Mesembryanthemum L.	107	Aetheorhiza Cass.	207	Echiochilon Desf.	307	Commelina Plum. ex L.	407	Schenkia Griseb.	507	Veronica L.	607	Triticum L.
8	Trianthema L.	108	Ageratum L.	208	Echium Tourn. ex L.	308	Calystegia R.Br.	408	Erodium L'Hér. ex Aiton	508	Limoniastrum Heist. ex Fabr.	608	Urochloa P.Beauv.
9	Zaleya Burm.f.	109	Ambrosia L.	209	Euploca Nutt.	309	Convolvulus L.	409	Geranium Tourn. ex L.	509	Limonium Mill.	609	Vossia Wall. & Griff.
10	Alisma L.	110	Anacyclus L.	210	Gastrocotyle Bunge	310	Cressa L.	410	Monsonia L.	510	Achnatherum P.Beauv.	610	Zea L.
11	Caldesia Parl.	111	Anthemis L.	211	Heliotropium Tourn. ex L.	311	Cuscuta L.	411	Gisekia L.	511	Acrachne Wight & Arn. ex Chiov.	611	Tristicha Thouars
12	Damasonium Mill.	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	Achyranthes L.	113	Asteriscus Moench	213	Microparacaryum (Popov ex Riedl)	313	Ipomoea L.	413	Elodea Michx.	513	Aeluropus Trin.	613	Atraphaxis L.
14	Aerva Forssk.	114	Atractylis L.	214	Moltkiopsis I.M.Johnst.	314	Seddera Hochst.	414	Halophila Thouars	514	Agropyron Gaertn.	614	Calligonum L.
15	Agathophora (Fenzl) Bunge	115	Baccharoides Moench	215	Nonea Medik.	315	Crassula L.	415	Najas L.	515	Alopecurus L.	615	Fallopia Adans.
16	Alternanthera Forssk.	116	Bidens L.	216	Ogastemma Brummitt	316	Umbilicus DC.	416	Ottelia Pers.	516	Ammochloa Boiss.	616	Persicaria Mill.
17	Amaranthus L.	117	Blainvillea Cass.	217	Podonosma Boiss.	317	Bryonia L.	417	Thalassia Banks & Sol. ex K.D.Koenig	517	Apera Adans.	617	Polygonum L.
18	Anabasis L.	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 Piirainen & G.Kadereit	119	Brocchia Vis.	219	Alyssum L.	319	Coccinia Wight & Arn.	419	Gladiolus Tourn. ex 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	Cymodocea K.D.Koenig	421	Juncus L.	521	Brachypodium P.Beauv.	621	Posidonia K.D.Koenig
22	Beta L.	122	Carlina L.	222	Brassica L.	322	Halodule Endl.	422	Ajuga L.	522	Briza 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	Chenopodiastrum 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	Ceruana Forssk.	225	Capsella Medik.	325	Thalassodendron Hartog	425	Coleus Lour.	525	Catapodium Link	625	Coris L.
26	Cornulaca Delile	126	Chiliadenus Cass.	226	Carrichtera DC.	326	Cynomorium L.	426	Lamium L.	526	Cenchrus L.	626	Lysimachia Tourn. ex L.
27	Digera Forssk.	127	Chlamydophora 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	Actiniopteris Link
29	Halocnemum M.Bieb.	129	Cichorium L.	229	Cuprella Salmerón-Sánchez, Mota & Fuert.	329	Cladium P.Browne	429	Marrubium L.	529	Coelachyrum Hochst. & Nees	629	Adiantum L.
30	Halopeplis 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	Dichasianthus 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	Ocimum L.	532	Corynephorus P.Beauv.	632	Adonis L.
33	Noaea Moq.	133	Crocodilium Hill	233	Diplotaxis DC.	333	Fuirena Rottb.	433	Orthosiphon Benth.	533	Crithopsis Jaub. & Spach	633	Anemone L.
34	Ouret Adans.	134	Crupina (Pers.) DC.	234	Enarthrocarpus Labill.	334	Isolepis 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	Dittrichia Greuter	237	Erucaria Gaertn.	337	Scirpoides Ség.	437	Pseudodictamnus Fabr.	537	Cynosurus L.	637	Caylusea A.St.-Hil.
38	Seidlitzia Bunge ex Boiss.	138	Echinops L.	238	Erucastrum (DC.) C.Presl	338	Pteridium Gleditsch	438	Salvia L.	538	Dactylis L.	638	Ochradenus Delile
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	Teucrium L.	540	Danthoniopsis Stapf	640	Randonia Coss.
41	Traganum Delile	141	Ethulia L.f.	241	Fibigia Medik.	341	Elatine L.	441	Thymbra L.	541	Desmazeria Dumort.	641	Reseda Tourn. ex L.
42	Allium L.	142	Filago Loefl.	242	Hornungia Rchb.	342	Ephedra Tourn. ex L.	442	Thymus L.	542	Desmostachya (Stapf) Stapf	642	Rhamnus L.
43	Narcissus L.	143	Flaveria Juss.	243	Isatis Tourn. ex L.	343	Chrozophora Neck. ex A.Juss.	443	Vitex L.	543	Dichanthium Willemet	643	Ziziphus Mill.
44	Nothoscordum Kunth	144	Garhadiolus Jaub. & Spach	244	Lepidium L.	344	Euphorbia L.	444	Volkameria L.	544	Digitaria Haller	644	Rhizophora L.
45	Pancratium Dill. ex L.	145	Gelasia Cass.	245	Leptaleum DC.	345	Mercurialis L.	445	Utricularia L.	545	Dinebra Jacq.	645	Crataegus L.
46	Pistacia L.	146	Geropogon L.	246	Lobularia Desv.	346	Ricinus L.	446	Gagea Salisb.	546	Diplachne 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 Pomel	348	Albizia Durazz.	448	Limeum L.	548	Ehrharta Thunb.	648	Sanguisorba L.
49	Ammodaucus Coss.	149	Gnomophalium Greuter	249	Matthiola W.T.Aiton	349	Alhagi Tourn. ex Gagnebin	449	Linum L.	549	Eleusine Gaertn.	649	Callipeltis Steven
50	Ammoides Adans.	150	Grangea Adans.	250	Morettia DC.	350	Anagyris L.	450	Lindernia All.	550	Elionurus Humb. & Bonpl. ex Willd.	650	Crucianella L.
51	Anthriscus Pers.	151	Gymnarrhena Desf.	251	Moricandia DC.	351	Anthyllis L.	451	Plicosepalus Tiegh.	551	Enneapogon Desv. ex P.Beauv.	651	Cruciata Mill.
52	Apium L.	152	Hedypnois Mill.	252	Nasturtiopsis Boiss.	352	Argyrolobium 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. & Schltdl.
54	Bupleurum L.	154	Helminthotheca Zinn	254	Neotorularia 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	Theligonum L.
57	Cyclospermum Lag.	157	Ifloga Cass.	257	Ochthodium DC.	357	Cassia L.	457	Gossypium L.	557	Hemarthria R.Br.	657	Valantia L.
58	Daucus L.	158	Iphiona Cass.	258	Pseuderucaria O.E.Schulz	358	Cicer L.	458	Grewia L.	558	Holcus L.	658	Ruppia L.
59	Deverra DC.	159	Koelpinia Pall.	259	Raphanus L.	359	Clitoria L.	459	Hermannia L.	559	Hordeum L.	659	Citrus L.
60	Ducrosia Boiss.	160	Lactuca L.	260	Rapistrum Crantz	360	Coronilla L.	460	Hibiscus L.	560	Hyparrhenia Andersson ex E.Fou	660	Haplophyllum A.Juss.
61	Eryngium Tourn. ex L.	161	Lasiopogon Cass.	261	Rorippa Scop.	361	Crotalaria 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	Schimpera 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.DC.) Wight & Arn.	464	Sida L.	564	Lasiurus Boiss.	664	Thesium L.
65	Leiotulus Ehrenb.	165	Limbarda Adans.	265	Sinapis L.	365	Ebenus L.	465	Mesembryanthemum... Marsilea L.	565	Leersia Sw.	665	Cardiospermum L.
66	Petroselinum Hill	166	Mantisalca Cass.	266	Sisymbrium L.	366	Erythrina L.	466	Cocculus DC.	566	Leptochloa P.Beauv.	666	Anticharis Endl.
67	Pimpinella L.	167	Matricaria L.	267	Zilla Forssk.	367	Faidherbia A.Chev.	467	Glinus L.	567	Leptothrium Kunth	667	Jamesbrittenia Kuntze
68	Scandix L.	168	Microglossa DC.	268	Commiphora Jacq.	368	Glycyrrhiza Tourn. ex L.	468	Ficus Tourn. ex L.	568	Lolium L.	668	Scrophularia Tourn. ex L.
69	Stoibrax Raf.	169	Nidorella Cass.	269	Campanula L.	369	Guilandina L.	469	Moringa Adans.	569	Lygeum Loefl. ex L.	669	Verbascum L.
70	Tordylium Tourn. ex L.	170	Notobasis Cass.	270	Legousia Durande	370	Haematoxylum L.	470	Neurada B.Juss.	570	Megathyrsus (Pilg.) B.K.Simon & S.W.L.Jacobs	670	Datura L.
71	Torilis Adans.	171	Onopordum L.	271	Wahlenbergia Schrad. ex Roth	371	Hippocrepis L.	471	Nitraria L.	571	Melanocenchris Nees	671	Hyoscyamus Tourn. ex L.
72	Visnaga 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	Maerua Forssk.	374	Leobordea Delile	474	Boerhavia Vaill. ex L.	574	Moorochloa Veldkamp	674	Nicotiana L.
75	Apterанthes 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	Pterocephalus Vaill. ex Adans.	377	Lupinus L.	477	Olea L.	577	Panicum L.	677	Withania Pauquy
78	Cynanchum L.	178	Pseudopodospermum (Lipsch. & Krasch.) Kuth	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	Melilotus Mill.	479	Ludwigia L.	579	Paspalum L.	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	Oxystelma R.Br.	181	Rhagadiolus Juss.	281	Arenaria Ruppius ex L.	381	Onobrychis Mill.	481	Ophioglossum L.	581	Phleum L.	681	Thymelaea Mill.
82	Pentatropis 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	Poa L.	683	Forsskaolea L.
84	Periploca Tourn. ex L.	184	Scorzoneroides 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	Orobanche L.	585	Rostraria Trin.	685	Urtica L.
86	Solenostemma Hayne	186	Silybum Adans.	286	Gymnocarpos Forssk.	386	Psophocarpus Neck. ex DC.	486	Parentucellia Viv.	586	Saccharum L.	686	Vahlia Thunb.
87	Arisarum Mill.	187	Sonchus L.	287	Gypsophila L.	387	Retama Raf.	487	Striga Lour.	587	Schismus 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	Eminium Schott	189	Spilanthes Jacq.	289	Loeflingia L.	389	Saraca L.	489	Argemone L.	589	Schoenefeldia Kunth	689	Priva Adans.
90	Lemna L.	190	Symphyotrichum Nees	290	Paronychia Mill.	390	Scorpiurus L.	490	Fumaria Tourn. ex L.	590	Setaria P.Beauv.	690	Verbena L.
91	Pistia L.	191	Tagetes L.	291	Petrorhagia (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	Polycarpaea Lam.	392	Senna Mill.	492	Hypecoum Tourn. ex L.	592	Sphenopus Trin.	692	Cyphostemma (Planch.) Alston
93	Wolffiella Hegelm.	193	Tripleurospermum Sch.Bip.	293	Polycarpon Loefl.	393	Sesbania Adans.	493	Papaver L.	593	Sporobolus R.Br.	693	Zostera L.
94	Hyphaene Gaertn.	194	Tussilago L.	294	Pteranthus Forssk.	394	Styphnolobium Schott	494	Sesamum L.	594	Stenotaphrum Trin.	694	Balanites Delile
95	Medemia Württemb. ex H.Wendl.	195	Urospermum Scop.	295	Rhodalsine J.Gay	395	Sulla Medik.	495	Peplidium Delile	595	Stipa L.	695	Seetzenia R.Br.
96	Phoenix L.	196	Verbesina L.	296	Sabulina Rchb.	396	Tamarindus Tourn. ex L.	496	Andrachne L.	596	Stipagrostis Nees	696	Tribulus L.
97	Asparagus Tourn. ex L.	197	Volutaria Cass.	297	Silene L.	397	Taverniera DC.	497	Flueggea Willd.	597	Stipellula Röser & Hamasha	697	Zygophyllum L.
98	Bellevalia Lapeyr.	198	Xanthium L.	298	Spergularia (Pers.) J.Presl & C.Presl	398	Tephrosia Pers.	498	Phyllanthus L.	598	Tetrapogon Desf.		
99	Dipcadi Medik.	199	Zoegea L.	299	Sphaerocoma T.Anderson	399	Trifolium Tourn. ex L.	499	Bacopa Aubl.	599	Themeda Forssk.		
100	Drimia Jacq. ex Willd.	200	Leontice L.	300	Stellaria L.	400	Trigonella L.	500	Globularia Tourn. ex L.	600	Thinopyrum Á.Löve		

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 figarei 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 schimperi Sch.Bip. ex Walp.	404	Launaea fragilis (Asso) Pau
5	Dicliptera paniculata (Forssk.) I.Darbysh.	105	Salicornia perennans Willd.	205	Visnaga daucoides Gaertn.	305	Blainvillea acmella (L.) Philipson	405	Launaea intybacea (Jacq.) Beauverd
6	Justicia heterocarpa T.Anderson	106	Salicornia perennis Mill.	206	Zosima absinthiifolia (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	Brocchia 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	Aizoanthemopsis 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	Aizoon 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.) Iliin	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 sinaicus Boiss.	313	Carduus getulus Pomel	413	Limbarda crithmoides (L.) Dumort.
14	Trianthema triquetrum Willd. ex Spreng.	114	Sevada schimperi Moq.	214	Leptadenia arborea (Forssk.) Schweinf.	314	Carduus pycnocephalus L.	414	Mantisalca salmantica (L.) Briq. & 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 Lej.	116	Suaeda altissima (L.) Pall.	216	Oxystelma esculentum (L.f.) Sm.	316	Carlina sicula Ten.	416	Matricaria chamomilla L.
17	Alisma plantago-aquatica L.	117	Suaeda fruticosa Forssk. ex J.F.Gmel.	217	Pentatropis nivalis (J.F.Gmel.) D.V.Field & J.R.I.Wood	317	Carthamus eriocephalus (Boiss.) Greuter	417	Microglossa pyrrhopappa (A.Rich.) Agnew
18	Caldesia parnassifolia (Bassi) Parl.	118	Suaeda maritima (L.) Dumort.	218	Pergularia tomentosa L.	318	Carthamus glaucus M.Bieb.	418	Nidorella aegyptiaca (L.) J.C.Manning & Goldblatt
19	Damasonium bourgaei Coss.	119	Suaeda monoica 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 greissii 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 tinctorius L.	422	Onopordum carduiforme Boiss.
23	Alternanthera pungens Kunth	123	Suaeda splendens (Pourr.) Gren. & Godr.	223	Biarum olivieri Blume	323	Centaurea 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	Centaurea alexandrina Delile	424	Osteospermum vaillantii (Decne.) Norl.
25	Amaranthus albus L.	125	Suaeda vermiculata Forssk. ex J.F.Gmel.	225	Lemna aequinoctialis Welw.	325	Centaurea bimorpha Viv.	425	Pallenis hierochuntica (Michon) Greuter
26	Amaranthus blitoides S.Watson	126	Traganum nudatum Delile	226	Lemna gibba L.	326	Centaurea calcitrapa L.	426	Pallenis spinosa (L.) Cass.
27	Amaranthus blitum L.	127	Allium ampeloprasum L.	227	Lemna minor L.	327	Centaurea eryngioides Lam.	427	Phagnalon barbeyanum Asch. & Schweinf.
28	Amaranthus caudatus L.	128	Allium artemisietorum Eig & Feinbrun	228	Pistia stratiotes L.	328	Centaurea furfuracea Coss. & Durieu	428	Phagnalon rupestre (L.) DC.
29	Amaranthus cruentus L.	129	Allium ascalonicum L.	229	Spirodela oligorrhiza (Kurz) Hegelm.	329	Centaurea glomerata Vahl	429	Phagnalon schweinfurthii Sch.Bip. ex Schweinf.
30	Amaranthus graecizans L.	130	Allium barthianum Asch. & Schweinf.	230	Spirodela polyrhiza (L.) Schleid.	330	Centaurea melitensis L.	430	Picris amalecitana (Boiss.) Eig
31	Amaranthus hybridus L.	131	Allium blomfieldianum Asch. & Schweinf.	231	Wolffiella hyalina (Delile) Monod	331	Centaurea pallescens Delile	431	Picris asplenioides L.
32	Amaranthus palmeri S.Watson	132	Allium cepa L.	232	Borassus aethiopum Mart.	332	Centaurea postii Boiss.	432	Picris cyanocarpa Boiss.
33	Amaranthus retroflexus L.	133	Allium coppoleri Tineo	233	Hyphaene thebaica (L.) Mart.	333	Centaurea pullata L.	433	Picris kotschyi Boiss.
34	Amaranthus spinosus L.	134	Allium crameri Asch. & Boiss.	234	Medemia argun (Mart.) Württemb. ex H.Wendl.	334	Centaurea scoparia Sieber ex Spreng.	434	Picris rhagadioloides (L.) Desf.
35	Amaranthus tricolor L.	135	Allium curtum Boiss. & Gaill.	235	Phoenix dactylifera L.	335	Centaurea sinaica DC.	435	Picris strigosa M.Bieb.
36	Amaranthus viridis L.	136	Allium desertorum Forssk.	236	Asparagus aphyllus L.	336	Centaurea solstitialis L.	436	Picris sulphurea Delile
37	Anabasis articulata (Forssk.) Moq.	137	Allium erdelii Zucc.	237	Asparagus horridus L.	337	Ceruana pratensis Forssk.	437	Pluchea dioscoridis (L.) DC.
38	Anabasis oropediorum Maire	138	Allium longanum Pamp.	238	Bellevalia eigii Feinbrun	338	Chiliadenus candicans (Delile) Brullo	438	Pseudoconyza viscosa (Mill.) D'Arcy
39	Anabasis setifera Moq.	139	Allium mareoticum Bornm. & Gauba	239	Bellevalia flexuosa Boiss.	339	Chiliadenus montanus (Vahl) Brullo	439	Pseudopodospermum undulatum (Vahl) Zaika, Sukhor. & N.Kilian
40	Arthrocaulon macrostachyum (Moric.) Piirainen & G.Kadereit	140	Allium myrianthum Boiss.	240	Bellevalia macrobotrys Boiss.	340	Chiliadenus sericeus (Batt. & Trab.) Brullo	440	Pulicaria arabica (L.) Cass.
41	Atriplex canescens (Pursh) Nutt.	141	Allium neapolitanum Cirillo	241	Bellevalia mauritanica Pomel	341	Chlamydophora tridentata Ehrenb. ex Less.	441	Pulicaria incisa (Lam.) DC.
42	Atriplex coriacea Forssk.	142	Allium orientale Boiss.	242	Bellevalia romana (L.) Sweet	342	Chrysanthellum indicum DC.	442	Pulicaria odora (L.) Rchb.
43	Atriplex dimorphostegia Kar. & Kir.	143	Allium pallens L.	243	Bellevalia salah-eidii 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	Bellevalia sessiliflora (Viv.) Kunth	344	Cichorium endivia L.	444	Pulicaria sicula (L.) Moris
45	Atriplex farinosa Forssk.	145	Allium sativum L.	245	Bellevalia trifoliata (Ten.) Kunth	345	Cichorium intybus L.	445	Pulicaria undulata (L.) C.A.Mey.
46	Atriplex glauca L.	146	Allium sphaerocephalon L.	246	Dipcadi 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. & Fourr.) J.C.Manning & Goldblatt	348	Cotula anthemoides L.	448	Reichardia tingitana (L.) Roth
49	Atriplex lindleyi Moq.	149	Allium trifoliatum Cirillo	249	Drimia palaestina M.B.Crespo, Mart.-Azorín & M.Á.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 nilotica Sukhor.	151	Nothoscordum gracile (Aiton) Stearn	251	Leopoldia bicolor (Boiss.) Eig & Feinbrun	351	Crepis libyca (Pamp.) Babc.	451	Scolymus maculatus L.
52	Atriplex nogalensis Friis & M.G.Gilbert	152	Pancratium arabicum Sickenb.	252	Leopoldia comosa (L.) Parl.	352	Crepis micrantha Czerep.	452	Scorzonera schweinfurthii Boiss.
53	Atriplex nummularia Lindl.	153	Pancratium maritimum L.	253	Leopoldia eburnea Eig & Feinbrun	353	Crepis nigricans Viv.	453	Scorzoneroides laciniata (Bertol.) Greuter
54	Atriplex patula L.	154	Pancratium sickenbergeri Asch. & Schweinf.	254	Muscari albiflorum (Täckh. & Boulos) Hosni	354	Crepis sancta (L.) Bornm.	454	Scorzoneroides 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	Crocodilium creticum (Boiss. & Heldr.) N.Garcia & Susanna	456	Senecio belbeysius Delile
57	Atriplex rosea L.	157	Pistacia lentiscus L.	257	Ornithogalum arabicum L.	357	Crocodilium pumilio (L.) N.Garcia & Susanna	457	Senecio flavus (Decne.) Sch.Bip.
58	Atriplex semibaccata R.Br.	158	Searsia tripartita (Ucria) Moffett	258	Ornithogalum narbonense 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 Waldst. & 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 Shayeb & F.Shehata	161	Ammoides pusilla (Brot.) Breistr.	261	Asphodelus ramosus L.	361	Dicoma tomentosa Cass.	461	Silybum marianum (L.) Gaertn.
62	Bassia aegyptiaca Turki, El Shayeb & 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 tenuifolius Cav.	363	Echinops galalensis 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 taeckholmianus Amin	466	Sonchus tenerrimus 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	Spilanthes costata Benth.
69	Caroxylon gaetulum (Maire) Akhani & Roalson	169	Bupleurum semicompositum L.	269	Ageratum conyzoides L.	369	Ethulia conyzoides L.	469	Symphyotrichum subulatum (Michx.) G.L.Nesom
70	Caroxylon imbricatum (Forssk.) Moq.	170	Bupleurum subovatum Link ex Spreng.	270	Ageratum houstonianum Mill.	370	Filago contracta (Boiss.) Chrtek & 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.Brig.) 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	Cyclospermum leptophyllum (Pers.) Sprague	275	Anthemis chia L.	375	Garhadiolus hedypnois 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	Chenopodiastrum murale (L.) S.Fuentes, Uotila & Borsch	178	Daucus glaber (Forssk.) Thell.	278	Anthemis fayedina Zareh	378	Glebionis coronaria (L.) Cass. ex Spach	478	Volutaria crupinoides (Desf.) Maire
79	Chenopodina anonyma Moq.	179	Daucus guttatus Sm.	279	Anthemis indurata Delile	379	Gnaphalium polycaulon Pers.	479	Volutaria lippii Cass.
80	Chenopodium album L.	180	Daucus pumilus (L.) Hoffmanns. & Link	280	Anthemis melampodina Delile	380	Gnaphalium uliginosum L.	480	Volutaria saharae (L.Chevall.) Wagenitz
81	Chenopodium ficifolium Sm.	181	Daucus syrticus Murb.	281	Anthemis microsperma Boiss. & Kotschy	381	Gnomophalium pulvinatum (Delile) Greuter	481	Volutaria sinaica (DC.) Wagenitz
82	Chenopodium giganteum D.Don	182	Deverra tortuosa (Desf.) DC.	282	Anthemis pseudocotula Boiss.	382	Grangea maderaspatana (L.) Poir.	482	Volutaria tubuliflora (Murb.) Sennen
83	Chenopodium moquinianum Aellen	183	Deverra triradiata 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	Ducrosia ismaelis Asch.	284	Anthemis zoharyana Eig	384	Hedypnois 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 monacantha 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 inculta 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 judaica L.	388	Helichrysum stoechas (L.) Moench	488	Anchusa acaulis 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.DC.
90	Halocnemum strobilaceum (Pall.) M.Bieb.	190	Ferula marmarica Asch. & Taub.	290	Artemisia scoparia Waldst. & Kit.	390	Heteroderis pusilla (Boiss.) Boiss.	490	Anchusa aggregata Lehm.
91	Halopeplis amplexicaulis (Vahl) Ung.-Sternb. ex Ces., Pass. & Gibelli	191	Foeniculum vulgare Mill.	291	Artemisia sieberi Besser	391	Hyoseris lucida L.	491	Anchusa hybrida Ten.
92	Halopeplis perfoliata (Forssk.) Bunge ex Ung.-Sternb.	192	Helosciadium nodiflorum (L.) W.D.J.Koch	292	Asteriscus aquaticus (L.) Less.	392	Hyoseris scabra L.	492	Anchusa milleri Lam. ex Spreng.
93	Haloxylon persicum Bunge	193	Leiotulus alexandrinus Ehrenb.	293	Asteriscus graveolens (Forssk.) Less.	393	Ifloga spicata (Forssk.) Sch.Bip.	493	Arnebia decumbens (Vent.) Coss. & Kralik
94	Haloxylon salicornicum (Moq.) Bunge ex Boiss.	194	Petroselinum crispum (Mill.) Fuss	294	Atractylis aristata Batt.	394	Iphiona mucronata (Forssk.) Asch. & Schweinf.	494	Arnebia hispidissima (Sieber ex Lehm.) A.DC.
95	Haloxylon scoparium Pomel	195	Pimpinella schweinfurthii Asch.	295	Atractylis cancellata L.	395	Iphiona scabra DC. ex Decne.	495	Arnebia linearifolia A.DC.
96	Haloxylon tamariscifolium (L.) Pau	196	Scandix pecten-veneris L.	296	Atractylis carduus (Forssk.) C.Chr.	396	Koelpinia linearis Pall.	496	Arnebia tinctoria Forssk.
97	Krascheninnikovia ceratoides (L.) Gueldenst.	197	Scandix stellata Banks & Sol.	297	Atractylis mernephthae Asch. & Schweinf. & Letourn.	397	Lactuca orientalis (Boiss.) Boiss.	497	Buglossoides arvensis (L.) I.M.Johnst.
98	Noaea mucronata (Forssk.) Asch. & Schweinf.	198	Stoibrax 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	Ouret lanata (L.) Kuntze	199	Tordylium aegyptiacum (L.) Poir.	299	Atractylis 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 schimperi (DC.) Isawumi, El-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 philaeana (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 sinaica (Boiss.) Boiss.	703	Silene succulenta Forssk.	803	Oceana serrulata (R.Br.) Byng & Christenh.	903	Ricinus communis L.
504	Echiochilon fruticosum Desf.	604	Nasturtiopsis 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	Neotorularia 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) Amo	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	Argyrolobium arabicum (Decne.) Jaub. & Spach
514	Gastrocotyle hispida (Forssk.) Bunge	614	Rorippa indica (L.) Hiern	714	Sphaerocoma hookeri T.Anderson	814	Cyperus alternifolius L.	914	Argyrolobium saharae Pomel
515	Heliotropium aegyptiacum Lehm.	615	Rorippa micrantha (B.Heyne ex Roth) Jonsell	715	Stellaria apetala Ucria	815	Cyperus articulatus L.	915	Argyrolobium 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 arbainense Fresen.	617	Savignya parviflora (Delile) Webb	717	Telephium sphaerospermum Boiss.	817	Cyperus compressus L.	917	Astragalus arpilobus Kar. & Kir.
518	Heliotropium bacciferum Forssk.	618	Schimpera arabica Hochst. & Steud.	718	Ceratophyllum demersum L.	818	Cyperus conglomeratus Rottb.	918	Astragalus asterias Steven
519	Heliotropium crispum Desf.	619	Schouwia purpurea (Forssk.) Schweinf.	719	Ceratophyllum muricatum Cham.	819	Cyperus difformis L.	919	Astragalus boeticus L.
520	Heliotropium curassavicum 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 hirsutissimum 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 kahiricum 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 hamosus 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 kahiricus DC.
529	Lappula spinocarpos (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 & Podlech	631	Wahlenbergia campanuloides (Delile) Vatke	731	Helianthemum ventosum Boiss.	831	Cyperus maculatus Boeckeler	931	Astragalus peregrinus Vahl
532	Moltkiopsis ciliata (Forssk.) I.M.Johnst.	632	Wahlenbergia lobelioides (L.f.) Link	732	Helianthemum vesicarium Boiss.	832	Cyperus michelianus (L.) Delile	932	Astragalus pseudosinaicus Gazer & Podlech
533	Nonea melanocarpa Boiss.	633	Cadaba farinosa Forssk.	733	Helianthemum virgatum (Desf.) Pers.	833	Cyperus mundii (Nees) Kunth	933	Astragalus schimperi 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. & Durieu ex Bonnet & Barratte) Brummitt	635	Capparis cartilaginea Decne.	735	Cleome arabica L.	835	Cyperus polystachyos Rottb.	935	Astragalus spinosus (Forssk.) Muschl.
536	Podonosma galalensis 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 ehrenbergii Schweinf.	638	Maerua crassifolia Forssk.	738	Cleome droserifolia (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 palaestina (L.) Raf.	740	Cleome pallida Kotschy	840	Eleocharis geniculata (L.) Roem. & Schult.	940	Astragalus vogelii (Webb) Bornm.
541	Arabis caucasica Willd.	641	Pterocephalus brevis Coult.	741	Cleome paradoxa R.Br. ex DC.	841	Eleocharis palustris (L.) Roem. & Schult.	941	Biserrula epiglottis (L.) Coulot, Rabaute & J.-M.Tison
542	Arabis engleriana Muschl.	642	Pterocephalus plumosus (L.) Coult.	742	Cleome scaposa DC.	842	Eleocharis parvula (Roem. & Schult.) Link ex Bluff, Nees & 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.) Huth
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 calcitrapae L.	745	Colchicum palaestinum (Baker) C.Archer	845	Fimbristylis ferruginea (L.) Vahl	945	Cassia fistula L.
546	Brassica rapa L.	646	Valeriana discoidea (L.) Willd.	746	Colchicum ritchii R.Br.	846	Fimbristylis turkestanica (Regel) B.Fedtsch.	946	Cicer arietinum L.
547	Cakile maritima Scop.	647	Valeriana szovitsiana (Fisch. & C.A.Mey.) Christenh. & Byng	747	Colchicum schimperi Janka ex Stef.	847	Fuirena ciliaris (L.) Roxb.	947	Cicer cuneatum Hochst. ex A.Rich.
548	Camelina hispida Boiss.	648	Valerianella petrovichii Asch.	748	Commelina benghalensis L.	848	Fuirena pubescens (Poir.) Kunth	948	Clitoria 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	Capsella bursa-pastoris (L.) Medik.	650	Atocion armeria (L.) Raf.	750	Commelina forskaolii Vahl	850	Schoenoplectiella articulata (L.) Lye	950	Coronilla securidaca L.
551	Carrichtera annua (L.) DC.	651	Cometes abyssinica R.Br. ex Wall.	751	Calystegia 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 guessfeldtianus Muschl.	753	Convolvulus arvensis L.	853	Schoenoplectiella senegalensis (Steud.) Lye	953	Crotalaria thebaica (Delile) DC.
554	Cuprella 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	Gymnocarpos decander Forssk.	755	Convolvulus fatmensis Kunze	855	Schoenoplectus corymbosus (Roth ex Roem. & Schult.) J.Raynal	955	Delonix elata (L.) Gamble
556	Dichasianthus runcinatus (Lag. ex DC.) V.I.Dorof.	656	Gymnocarpos sclerocephalus (Decne.) Dahlgren & Thulin	756	Convolvulus glomeratus Choisy	856	Schoenoplectus subulatus (Vahl) Lye	956	Delonix regia (Bojer ex Hook.) Raf.
557	Didesmus aegyptius (L.) Desv.	657	Gypsophila capillaris (Forssk.) C.Chr.	757	Convolvulus humilis Jacq.	857	Schoenoplectus triqueter (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 DC.	759	Convolvulus lanatus Vahl	859	Pteridium aquilinum (L.) Kuhn	959	Erythrina crista-galli L.
560	Diplotaxis erucoides (L.) DC.	660	Herniaria cyrenaica 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 × schweinfurthii O.E.Schulz	664	Herniaria lenticulata Forssk.	764	Convolvulus rhyniospermus Hochst. ex Choisy	864	Elatine macropoda Guss.	964	Glycine moringiflora Delile
565	Enarthrocarpus lyratus (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 strangulatus Boiss.	667	Paronychia argentea Lam.	767	Convolvulus stachydifolius Choisy	867	Ephedra ciliata Fisch. & C.A.Mey.	967	Haematoxylum campechianum L.
568	Eremobium aegyptiacum (Spreng.) Asch. ex Boiss.	668	Paronychia capitata (L.) Lam.	768	Cressa cretica L.	868	Chrozophora brocchiana Vis.	968	Hippocrepis areolata Desv.
569	Erucaria crassifolia (Forssk.) Delile	669	Paronychia sinaica 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	Polycarpaea repens (Forssk.) Asch. & Schweinf.	771	Cuscuta campestris Yunck.	871	Euphorbia arabica Hochst. & Steud. ex T.Anderson	971	Hippocrepis cyclocarpa Murb.
572	Erucaria pinnata (Viv.) Täckh. & Boulos	672	Polycarpaea robbairea (Kuntze) Greuter & Burdet	772	Cuscuta epilinum Weihe	872	Euphorbia arguta Banks & Sol.	972	Hippocrepis unisiliquosa L.
573	Erucastrum arabicum Fisch. & C.A.Mey.	673	Polycarpaea spicata Wight ex Arn.	773	Cuscuta monogyna Vahl	873	Euphorbia bivonae Steud.	973	Indigofera argentea Burm.f.
574	Eruca vesicaria (L.) Cav.	674	Polycarpon alsinifolium (Biv.) DC.	774	Cuscuta palaestina 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 chamaesyce L.	975	Indigofera coerulea 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	Farsetia aegyptia Turra	677	Polycarpon tetraphyllum (L.) L.	777	Dichondra micrantha Urb.	877	Euphorbia dendroides L.	977	Indigofera cordifolia B.Heyne ex Roth
578	Farsetia longisiliqua Decne.	678	Pteranthus dichotomus Forssk.	778	Ipomoea batatas (L.) Lam.	878	Euphorbia dracunculoides Lam.	978	Indigofera denudata Schrank
579	Farsetia stylosa R.Br.	679	Rhodalsine geniculata (Poir.) F.N.Williams	779	Ipomoea biflora (L.) Pers.	879	Euphorbia exigua L.	979	Indigofera hochstetteri Baker
580	Fibigia clypeata (L.) Medik.	680	Sabulina mediterranea (Ledeb. ex Link) Rchb.	780	Ipomoea cairica (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 forskaolii J.Gay	981	Indigofera oblongifolia Forssk.
582	Isatis lusitanica L.	682	Silene aegyptiaca (L.) L.f.	782	Ipomoea eriocarpa 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 inaequilatera Sond.	986	Lathyrus aphaca L.
587	Lepidium draba L.	687	Silene biappendiculata 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 nubica N.E.Br.	988	Lathyrus hirsutus L.
589	Lepidium niloticum (Delile) Sieber	689	Silene colorata Poir.	789	Seddera arabica (Forssk.) Choisy	889	Euphorbia oxyodonta Boiss.	989	Lathyrus marmoratus Boiss. & Balansa
590	Lepidium sativum L.	690	Silene coniflora Nees ex Otth	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 peplis L.	992	Lathyrus sativus L.
593	Lobularia libyca (Viv.) Meisn.	693	Silene forskohlei Steud.	793	Umbilicus intermedius Boiss.	893	Euphorbia peplus 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.	895	Euphorbia polyacantha 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 scordiifolia Jacq.	998	Lotus arabicus Sol. ex L.
599	Matthiola parviflora (Schousb.) W.T.Aiton	699	Silene oliveriana Otth	799	Cucumis prophetarum L.	899	Euphorbia serpens Kunth	999	Lotus arenarius Brot.
600	Morettia canescens Boiss.	700	Silene pendula L.	800	Cymodocea nodosa (Ucria) Asch.	900	Euphorbia sintenisii Boiss. ex Freyn	1000	Lotus corniculatus L.

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 cytisoides L.	1102	Trifolium resupinatum L.	1202	Lavandula pubescens Decne.	1302	Glinus runkewitzii Täckh. & Boulos	1402	Plantago amplexicaulis Cav.
1003	Lotus edulis L.	1103	Trifolium scabrum L.	1203	Lavandula saharica 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 gebelia Vent.	1105	Trifolium tomentosum L.	1205	Leucas neuflizeana Courbon	1305	Ficus salicifolia Vahl	1405	Plantago crassifolia Forssk.
1006	Lotus glinoides Delile	1106	Trigonella anguina Delile	1206	Marrubium alysson L.	1306	Ficus sycomorus L.	1406	Plantago crypsoides Boiss.
1007	Lotus halophilus Boiss. & Spruner	1107	Trigonella arabica Delile	1207	Mentha longifolia (L.) L.	1307	Moringa peregrina (Forssk.) Fiori	1407	Plantago cylindrica Forssk.
1008	Lotus hebranicus Hochst. ex Brand	1108	Trigonella berythea Boiss. & C.I.Blanche	1208	Mentha pulegium L.	1308	Neurada procumbens L.	1408	Plantago exigua Murray
1009	Lotus nubicus Hochst. ex Baker	1109	Trigonella cylindracea Desv.	1209	Mentha spicata L.	1309	Nitraria retusa (Forssk.) Asch.	1409	Plantago indica L.
1010	Lotus ornithopodioides L.	1110	Trigonella glabra Thunb.	1210	Mentha × piperita L.	1310	Peganum harmala L.	1410	Plantago lagopus L.
1011	Lotus palustris Willd.	1111	Trigonella laciniata L.	1211	Micromeria nervosa (Desf.) Benth.	1311	Tetradiclis tenella (Ehrenb.) Litv.	1411	Plantago lanceolata L.
1012	Lotus pedunculatus Cav.	1112	Trigonella maritima Delile ex Poir.	1212	Ocimum forskoelei Benth.	1312	Boerhavia coccinea Mill.	1412	Plantago major L.
1013	Lotus peregrinus L.	1113	Trigonella media Delile ex Urb.	1213	Orthosiphon pallidus Royle ex Benth.	1313	Boerhavia diandra L.	1413	Plantago notata Lag.
1014	Lotus polyphyllos E.D.Clarke	1114	Trigonella occulta Delile ex Ser.	1214	Otostegia fruticosa (Forssk.) Schweinf. ex Penzig	1314	Boerhavia diffusa L.	1414	Plantago ovata Forssk.
1015	Lotus tenuis Waldst. & Kit. ex Willd.	1115	Trigonella stellata Forssk.	1215	Phlomis floccosa D.Don	1315	Boerhavia repens L.	1415	Plantago phaeostoma Boiss. & Heldr.
1016	Lotus tetragonolobus L.	1116	Trigonella × schweinfurthiana Muschl.	1216	Prasium majus L.	1316	Commicarpus helenae (Roem. & Schult.) Meikle	1416	Plantago squarrosa Murray
1017	Lupinus albus L.	1117	Trigonella × sickenbergeriana Muschl.	1217	Pseudodictamnus damascenus (Boiss.) Salmaki & Siadati	1317	Nymphaea lotus L.	1417	Plantago weldenii Rchb.
1018	Lupinus angustifolius L.	1118	Tripodion tetraphyllum (L.) Fourr.	1218	Pseudodictamnus mediterraneus Salmaki & Siadati	1318	Nymphaea micrantha Guill. & Perr.	1418	Veronica anagallis-aquatica L.
1019	Lupinus digitatus Forssk.	1119	Vachellia etbaica (Schweinf.) Kyal. & Boatwr.	1219	Salvia aegyptiaca L.	1319	Nymphaea nouchali Burm.f.	1419	Veronica anagalloides Guss.
1020	Medicago arabica (L.) Huds.	1120	Vachellia flava (Forssk.) Kyal. & Boatwr.	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 palaestina Benth.	1321	Epilobium hirsutum L.	1421	Veronica catenata Pennell
1022	Medicago granadensis Willd.	1122	Vachellia oerfota (Forssk.) Kyal. & Boatwr.	1222	Salvia rosmarinus Spenn.	1322	Ludwigia adscendens (L.) H.Hara	1422	Veronica persica Poir.
1023	Medicago hypogaea E.Small	1123	Vachellia seyal (Delile) 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 laciniata (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	Limoniastrum guyonianum Durieu ex Boiss.
1027	Medicago lupulina L.	1127	Vicia hirsuta (L.) Gray	1227	Teucrium polium C.Presl	1327	Bellardia trixago (L.) All.	1427	Limoniastrum monopetalum (L.) Boiss.
1028	Medicago marina L.	1128	Vicia hybrida L.	1228	Teucrium leucocladum Boiss.	1328	Cistanche phelypaea (L.) Cout.	1428	Limonium avei (De Not.) Brullo & Erben
1029	Medicago minima (L.) Bartal.	1129	Vicia lutea L.	1229	Thymbra 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.) Vatke	1430	Limonium bonduellei (T.Lestib.) Kuntze
1031	Medicago orbicularis (L.) Bartal.	1131	Vicia narbonensis L.	1231	Vitex agnus-castus L.	1331	Orobanche aegyptiaca Pers.	1431	Limonium echioides (L.) Mill.
1032	Medicago pedunculata Ehrenb. ex Sweet	1132	Vicia parviflora Cav.	1232	Volkameria acerbiana Vis.	1332	Orobanche cernua Loefl.	1432	Limonium lobatum (L.f.) Chaz.
1033	Medicago polyceratia (L.) Sauvages ex Trautv.	1133	Vicia peregrina L.	1233	Utricularia gibba L.	1333	Orobanche crenata Forssk.	1433	Limonium narbonense Mill.
1034	Medicago polymorpha L.	1134	Vicia sativa L.	1234	Utricularia inflexa Forssk.	1334	Orobanche grisebachii Reut.	1434	Limonium pruinosum (L.) Chaz.
1035	Medicago rigidula (L.) All.	1135	Vicia serratifolia Jacq.	1235	Gagea dayana Chodat & Beauverd	1335	Orobanche 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	Orobanche minor Sm.	1436	Limonium sinuatum (L.) Mill.
1037	Medicago truncatula Gaertn.	1137	Vicia villosa Roth	1237	Gagea rigida Boiss. & Spruner	1337	Orobanche mutelii F.W.Schultz	1437	Limonium tubiflorum (Delile) Kuntze
1038	Medicago turbinata (L.) All.	1138	Vigna luteola (Jacq.) Benth.	1238	Tulipa biflora Pall.	1338	Orobanche nana Noë ex Rchb.	1438	Limonium zanonii (Pamp.) Domina
1039	Melilotus albus Medik.	1139	Vigna unguiculata (L.) Walp.	1239	Linum decumbens Desf.	1339	Orobanche portoilicitana A.Pujadas & M.B.Crespo	1439	Statice boissieri Lafont
1040	Melilotus elegans Salzm. ex Ser.	1140	Frankenia hirsuta L.	1240	Linum pubescens Banks & Sol.	1340	Orobanche pubescens d'Urv.	1440	Achnatherum parviflorum (Desf.) M.Nobis
1041	Melilotus indicus (L.) All.	1141	Frankenia pulverulenta L.	1241	Linum strictum L.	1341	Orobanche ramosa L.	1441	Acrachne racemosa (B.Heyne ex Roth) Ohwi
1042	Melilotus segetalis (Brot.) Ser.	1142	Centaurium maritimum (L.) Fritsch	1242	Linum usitatissimum L.	1342	Orobanche schultzii Mutel	1442	Aegilops bicornis (Forssk.) Jaub. & Spach
1043	Melilotus serratifolius Täckh. & Boulos	1143	Centaurium pulchellum (Sw.) Hayek ex Hand.-Mazz., Stadlm., Janch. & Faltis	1243	Lindernia parviflora (Roxb.) Haines	1343	Orobanche 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 kotschyi Boiss.
1045	Melilotus sulcatus Desf.	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 arborescens (Desf.) Willd.	1246	Ammannia auriculata Willd.	1346	Striga gesnerioides (Willd.) Vatke	1446	Aegilops peregrina (Hack.) Maire & Weiller
1047	Onobrychis crista-galli (L.) Lam.	1147	Erodium chium (L.) Willd.	1247	Ammannia baccifera L.	1347	Striga hermonthica (Delile) Benth.	1447	Aegilops ventricosa Tausch
1048	Onobrychis ptolemaica (Delile) 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	Lawsonia 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 palaestina 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 gaillardotii Boiss.	1454	Apera 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 Delile ex Godr.	1256	Abutilon bidentatum Hochst. ex A.Rich.	1356	Fumaria microstachys Kralik ex Hausskn.	1456	Aristida funiculata Trin. & Rupr.
1057	Pithecellobium dulce (Roxb.) Benth.	1157	Erodium oxyrhinchum 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 Delile	1259	Abutilon grandifolium (Willd.) Sweet	1359	Glaucium arabicum Fresen.	1459	Avena barbata Pott ex Link
1060	Psophocarpus tetragonolobus (L.) DC.	1160	Erodium touchyanum Delile ex Godr.	1260	Abutilon pannosum (G.Forst.) Schltdl.	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 mascatense 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 heliotropioides (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 trilocularis 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 alopecuros Poir.
1069	Senna alexandrina Mill.	1169	Gisekia pharnaceoides L.	1269	Gossypium herbaceum L.	1369	Papaver decaisnei Hochst. & Steud. ex Elkan	1469	Bromus catharticus Vahl
1070	Senna bicapsularis (L.) Roxb.	1170	Myriophyllum spicatum L.	1270	Grewia erythraea Schweinf.	1370	Papaver dodecandrum (Forssk.) Medik.	1470	Bromus diandrus Roth
1071	Senna holosericea (Fresen.) Greuter	1171	Elodea 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	Hermannia modesta (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 Leyss.
1074	Sesbania sericea (Willd.) Link	1174	Najas graminea Delile	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 (Parl.) 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 telephioides 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 kassasii Boulos	1181	Vallisneria spiralis L.	1281	Malva parviflora L.	1381	Phyllanthus rotundifolius J.G.Klein ex Willd.	1481	Bromus rubens L.
1082	Tephrosia nubica (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 phillipsiae Baker f.	1385	Kickxia aegyptiaca (L.) Nábelek	1485	Catapodium 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 fontanesii J.Gay ex Laharpe	1287	Pavonia burchellii (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 kotschyi 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 punctorius L.f.	1290	Pavonia triloba Guill. & Perr.	1390	Linaria albifrons (Sm.) Spreng.	1490	Cenchrus divisus (J.F.Gmel.) Verloove, Govaerts & Buttler
1091	Trifolium chrysopogon Viv.	1191	Juncus rigidus Desf.	1291	Sida acuta Burm.f.	1391	Linaria chalepensis (L.) Mill.	1491	Cenchrus echinatus L.
1092	Trifolium clusii Godr.	1192	Juncus subulatus Forssk.	1292	Sida alba L.	1392	Linaria haelava (Forssk.) Delile	1492	Cenchrus longisetus M.C.Johnst.
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 dasyurum C.Presl	1194	Clerodendrum capitatum (Willd.) Schumach.	1294	Sida spinosa L.	1394	Linaria tenuis (Viv.) Spreng.	1494	Cenchrus pennisetiformis Steud.
1095	Trifolium ehrenbergii Sweet	1195	Clerodendrum formicarum Gürke	1295	Marsilea aegyptiaca Willd.	1395	Misopates microcarpum (Pomel) D.A.Sutton	1495	Cenchrus setaceus (Forssk.) Morrone
1096	Trifolium fragiferum L.	1196	Clerodendrum 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 (Schltdl.) 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 forskaolii (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 pycnothrix Trin.	1602	Panicum miliaceum 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.) Soják	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 (Pourr.) Breistr.	1607	Parapholis marginata Runemark	1707	Persicaria limbata (Meisn.) H.Hara	1807	Galium nigricans Boiss.	1907	Verbena officinalis L.
1508	Crithopsis delileana (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 scorpiuroides Coss.
1510	Cutandia maritima (L.) Barbey	1610	Paspalum racemosum Lam.	1710	Persicaria senegalensis (Meisn.) Soják	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 Schnizl.	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	Seetzenia lanata (Willd.) Bullock
1514	Cymbopogon martini (Roxb.) W.Watson	1614	Phalaris canariensis L.	1714	Polygonum maritimum L.	1814	Oldenlandia corymbosa L.	1914	Seetzenia orientalis Decne.
1515	Cymbopogon nardus (L.) Rendle	1615	Phalaris minor Retz.	1715	Polygonum melastomaca Delile	1815	Plocama calycoptera (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 plebeium R.Br.	1817	Theligonum cynocrambe L.	1917	Tribulus megistopterus Kralik
1518	Cynodon transvaalensis Burtt 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	Cynosurus coloratus Lehm. ex Steud.	1619	Phragmites mauritianus Kunth	1719	Rumex calthifolius Campd.	1819	Valantia hispida L.	1919	Tribulus pentandrus Forssk.
1520	Cynosurus echinatus L.	1620	Poa annua L.	1720	Rumex crispus L.	1820	Ruppia cirrhosa (Petagna) Grande	1920	Tribulus spurius Kralik
1521	Dactylis glomerata L.	1621	Poa diaphora Trin.	1721	Rumex cyprius Murb.	1821	Ruppia 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 scindicum Boiss.	1623	Poa sinaica Steud.	1723	Rumex pictus Forssk.	1823	Haplophyllum tuberculatum (Forssk.) A.Juss.	1923	Zygophyllum album L.f.
1524	Danthoniopsis barbata (Nees) C.E.Hubb.	1624	Polypogon maritimus Willd.	1724	Rumex pulcher L.	1824	Populus euphratica Olivier	1924	Zygophyllum arabicum (L.) Christenh. & Byng
1525	Desmazeria philistaea (Boiss.) H.Scholz	1625	Polypogon monspeliensis (L.) Desf.	1725	Rumex simpliciflorus Murb.	1825	Salix mucronata Thunb.	1925	Zygophyllum bruguieri (DC.) Christenh. & Byng
1526	Desmostachya bipinnata (L.) Stapf	1626	Polypogon viridis (Gouan) Breistr.	1726	Rumex spinosus L.	1826	Salix tetrasperma Roxb.	1926	Zygophyllum coccineum L.
1527	Dichanthium annulatum (Forssk.) Stapf	1627	Rostraria cristata (L.) Tzvelev	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 (Lam.) Tzvelev	1729	Pontederia natans P.Beauv.	1829	Thesium humile Vahl	1929	Zygophyllum dumosum Boiss.
1530	Digitaria sanguinalis (L.) Scop.	1630	Rostraria rohlfsii (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 cypria Danin	1831	Mimusops laurifolia (Forssk.) Friis	1931	Zygophyllum glutinosum (Delile) Christenh. & Byng
1532	Digitaria violascens Link	1632	Saccharum spontaneum L.	1732	Portulaca granulatostellulata (Poelln.) Ricceri & Arrigoni	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) Ricceri & Arrigoni	1833	Anticharis glandulosa Asch.	1933	Zygophyllum mayanum (Schltdl.) 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 & Vierh.) 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	Potamogeton perfoliatus L.	1840	Verbascum letourneuxii 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. & Schltdl.	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	Enteropogon prieurii (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.) Täckh.		
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 (Piller & 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	Actiniopteris 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.		
1558	Eragrostis pilosa (L.) P.Beauv.	1658	Stenotaphrum secundatum (Walter) Kuntze	1758	Adonis microcarpa DC.	1858	Nicotiana tabacum L.		
1559	Eragrostis sarmentosa (Thunb.) Trin.	1659	Stipagrostis acutiflora (Trin. & Rupr.) De Winter	1759	Anemone coronaria L.	1859	Physalis angulata L.		
1560	Eragrostis tef (Zuccagni) 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 hirtigluma (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 forskaolii 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 phleoides (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 uniplumis (Licht.) De Winter	1769	Ranunculus muricatus L.	1869	Solanum memphiticum J.F.Gmel.		
1570	Hemarthria altissima (Poir.) Stapf & C.E.Hubb.	1670	Stipagrostis vulnerans (Trin. & Rupr.) De Winter	1770	Ranunculus rionii Lagger	1870	Solanum nigrum L.		
1571	Holcus annuus Salzm. ex C.A.Mey.	1671	Stipa lagascae Roem. & Schult.	1771	Ranunculus saniculifolius Viv.	1871	Solanum pseudocapsicum L.		
1572	Hordeum marinum Huds.	1672	Stipa letourneuxii Trab.	1772	Ranunculus sceleratus 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	Tetrapogon villosus Desf.	1774	Ranunculus trichophyllus Chaix	1874	Solanum seaforthianum Andrews		
1575	Hordeum vulgare L.	1675	Themeda triandra Forssk.	1775	Caylusea hexagyna (Forssk.) M.L.Green	1875	Solanum villosum Mill.		
1576	Hyparrhenia 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 Henrard	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	Triraphis pumilio R.Br.	1783	Reseda luteola L.	1883	Tamarix amplexicaulis Ehrenb.		
1584	Lolium arundinaceum (Schreb.) Darbysh.	1684	Trisetaria glumacea (Boiss.) Maire	1784	Reseda muricata C.Presl	1884	Tamarix aphylla (L.) H.Karst.		
1585	Lolium mediterraneum (Hack.) Banfi, Galasso, Foggi, Kopecký & Ardenghi	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 phyteuma 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 (Schumach.) H.Scholz	1789	Reseda urnigera Webb	1889	Tamarix tetragyna Ehrenb.		
1590	Lygeum spartum Loefl. ex L.	1690	Urochloa leersioides (Hochst.) A.M.Torres & C.M.Morton	1790	Rhamnus disperma Ehrenb. ex Boiss.	1890	Thymelaea hirsuta (L.) Endl.		
1591	Megathyrsus 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	Melanocenchris 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 reptans (L.) Stapf	1794	Ziziphus spina-christi (L.) Desf.	1894	Forsskaolea viridis Ehrenb. ex Webb		
1595	Moorochloa eruciformis (Sm.) Veldkamp	1695	Vossia cuspidata (Roxb.) Griff.	1795	Rhizophora mucronata Poir.	1895	Parietaria alsinefolia Delile		
1596	Oloptum miliaceum (L.) Röser & Hamasha	1696	Zea mays L.	1796	Crataegus azarolus L.	1896	Parietaria judaica L.		
1597	Oryza sativa L.	1697	Zea mexicana (Schrad.) Kuntze	1797	Potentilla supina L.	1897	Urtica pilulifera L.		
1598	Panicum antidotale Retz.	1698	Tristicha trifaria (Bory ex Willd.) Spreng.	1798	Rubus creticus Tourn. ex L.	1898	Urtica urens L.		
1599	Panicum coloratum L.	1699	Polygala erioptera DC.	1799	Rubus ulmifolius Schott	1899	Vahlia dichotoma (Murray) Kuntze		
1600	Panicum figarei Tod.	1700	Polygala irregularis Boiss.	1800	Callipeltis cucullaris (L.) DC.	1900	Vahlia digyna (Retz.) Kuntze		

Table C: Native Species in Egypt: Subspecies

Table (C) Native Subspecies 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 subsp. marina	46	Helichrysum stoechas subsp. barrelieri (Ten.) Nymar	91	Cuscuta monogyna subsp. monogyna	136	Trifolium repens subsp. repens	181	Centropodia forskaolii subsp. forskaolii
2	Alisma plantago-aquatica subsp. plantago-aquatica	47	Hyoseris lucida subsp. lucida	92	Ipomoea carnea subsp. carnea	137	Trigonella glabra subsp. glabra	182	Cymbopogon schoenanthus subsp. proximus (Hochst. ex A.Rich.) Maire & Weiller
3	Amaranthus blitum subsp. oleraceus (L.) Costea	48	Ifloga spicata subsp. elbaensis	93	Cynomorium coccineum subsp. coccineum	138	Tripodion tetraphyllum subsp. tetraphyllum	183	Dactylis glomerata subsp. glomerata
4	Amaranthus graecizans subsp. silvestris (Vill.) Brenan	49	Ifloga spicata subsp. hadidii (Fayed & Zareh) Greute	94	Carex distans subsp. distans	139	Vachellia etbaica subsp. etbaica	184	Dactylis glomerata subsp. hispanica (Roth) Nyman
5	Atriplex glauca subsp. palaestina (Boiss.) Dobignard	50	Ifloga spicata subsp. labillardierei (Pamp.) Chrtek	95	Cladium mariscus subsp. mariscus	140	Vachellia nilotica subsp. indica (Benth.) Kyal. & Boatwr.	185	Diplachne fusca subsp. fusca
6	Atriplex lindleyi subsp. inflata (F.Muell.) Paul G.Wilson	51	Ifloga spicata subsp. spicata	96	Cyperus alternifolius subsp. flabelliformis Kük.	141	Vachellia nilotica subsp. nilotica	186	Elymus farctus subsp. rechingeri (Runemark) Melderis
7	Allium curtum subsp. curtum	52	Lactuca orientalis subsp. orientalis	97	Cyperus conglomeratus subsp. conglomeratus	142	Vachellia nilotica subsp. tomentosa (Benth.) Kyal. & Boatwr.	187	Holcus annuus subsp. setiglumis (Boiss. & Reut.) M.Seq. & Castrov.
8	Allium sphaerocephalon subsp. arvense (Guss.) Arcang.	53	Launaea fragilis subsp. tenuiloba (Boiss.) Zareh & M.H.Mohamed	98	Cyperus digitatus subsp. auricomus (Sieber ex Spreng.) Kük.	143	Vachellia tortilis subsp. raddiana (Savi) Kyal. & Boatwr.	188	Hordeum marinum subsp. gussoneanum (Parl.) Thell.
9	Narcissus tazetta subsp. tazetta	54	Launaea mucronata subsp. cassiniana (Jaub. & Spac N.Kilian	99	Cyperus laevigatus subsp. distachyos (All.) Ball	144	Vachellia tortilis subsp. tortilis	189	Hordeum marinum subsp. marinum
10	Eryngium tricuspidatum subsp. occidentalis Wörz	55	Launaea mucronata subsp. mucronata	100	Cyperus laevigatus subsp. laevigatus	145	Vicia lutea subsp. lutea	190	Hordeum murinum subsp. glaucum (Steud.) Tzvelev
11	Apteranthes europaea subsp. europaea	56	Limbarda crithmoides subsp. longifolia (Arcang.) Greuter	101	Cyperus longus subsp. longus	146	Vicia monantha subsp. monantha	191	Hordeum murinum subsp. leporinum (Link) Arcang.
12	Cynanchum acutum subsp. acutum	57	Pallenis spinosa subsp. asteroidea (Viv.) Greuter	102	Cyperus maculatus subsp. maculatus	147	Vicia peregrina subsp. peregrina	192	Leptochloa panicea subsp. panicea
13	Cynanchum boveanum subsp. boveanum	58	Pallenis spinosa subsp. spinosa	103	Cyperus michelianus subsp. pygmaeus (Rottb.) As & Graebn.	148	Vicia sativa subsp. nigra Ehrh.	193	Lolium arundinaceum subsp. arundinaceum
14	Cynanchum boveanum subsp. nubicum (Decne.) Khanu & Liede	59	Phagnalon rupestre subsp. rupestre	104	Cyperus papyrus subsp. papyrus	149	Vicia sativa subsp. sativa	194	Phragmites australis subsp. australis
15	Arisarum vulgare subsp. clusii (Schott) K.Richt.	60	Picris asplenioides subsp. asplenioides	105	Eleocharis palustris subsp. iranica Kukkonen	150	Vicia villosa subsp. varia (Host) Corb.	195	Phragmites australis subsp. isiacus (Arcang.) ined.
16	Asparagus aphyllus subsp. aphyllus	61	Picris strigosa subsp. strigosa	106	Schoenoplectiella erecta subsp. erecta	151	Erodium pulverulentum subsp. tunetanum (DC.) Guitt.	196	Saccharum spontaneum subsp. aegyptiacum (Willd.) Hack.
17	Asparagus aphyllus subsp. orientalis (Baker) P.H.Davis	62	Pseudopodospermum undulatum subsp. undulatum	107	Scirpoides holoschoenus subsp. holoschoenus	152	Halophila ovalis subsp. ovalis	197	Saccharum spontaneum subsp. spontaneum
18	Bellevalia macrobotrys subsp. macrobotrys	63	Pulicaria undulata subsp. undulata	108	Euclea racemosa subsp. schimperi (A.DC.) F.White	153	Najas marina subsp. marina	198	Stipa letourneuxii subsp. letourneuxii
19	Asphodelus ramosus subsp. ramosus	64	Pulicaria vulgaris subsp. vulgaris	109	Ephedra alata subsp. alenda (Stapf) Trab.	154	Juncus acutus subsp. acutus	199	Tricholaena teneriffae subsp. teneriffae
20	Achillea maritima subsp. maritima	65	Scolymus hispanicus subsp. hispanicus	110	Euphorbia bivonae subsp. bivonae	155	Juncus acutus subsp. leopoldii (Parl.) Snogerup	200	Triticum aestivum subsp. aestivum
21	Aetheorhiza bulbosa subsp. bulbosa	66	Senecio glaucus subsp. coronopifolius (Maire) C.Alexander	111	Euphorbia cuneata subsp. cuneata	156	Juncus fontanesii subsp. pyramidatus (Laharpe) Snogeru	201	Triticum turgidum subsp. dicoccum (Schrank ex Schübl.) Thel
22	Anacyclus monanthos subsp. monanthos	67	Senecio glaucus subsp. glaucus	112	Euphorbia dracunculoides subsp. dracunculoides	157	Lamium amplexicaule subsp. amplexicaule	202	Triticum turgidum subsp. durum (Desf.) Husn.
23	Anthemis arvensis subsp. arvensis	68	Senecio vulgaris subsp. vulgaris	113	Euphorbia exigua subsp. exigua	158	Mentha longifolia subsp. typhoides (Briq.) Harley	203	Triticum turgidum subsp. polonicum (L.) Thell.
24	Artemisia judaica subsp. judaica	69	Sonchus asper subsp. glaucescens (Jord.) Ball	114	Euphorbia falcata subsp. falcata	159	Mentha spicata subsp. condensata (Briq.) Greuter & Bur	204	Triticum turgidum subsp. turgidum
25	Asteriscus graveolens subsp. graveolens	70	Sonchus maritimus subsp. maritimus	115	Euphorbia helioscopia subsp. helioscopia	160	Mentha spicata subsp. spicata	205	Zea mays subsp. mays
26	Carduus pycnocephalus subsp. breviphyllarius P.H.Davis	71	Sonchus tenerrimus subsp. tenerrimus	116	Astragalus arpilobus subsp. hauarensis (Boiss.) Podlech	161	Otostegia fruticosa subsp. fruticosa	206	Tristicha trifaria subsp. pulchella (Wedd.) C.Cusset & G.Cusse
27	Carduus pycnocephalus subsp. pycnocephalus	72	Volutaria lippii subsp. lippii	117	Hippocrepis unisiliquosa subsp. unisiliquosa	162	Pseudodictamnus mediterraneus subsp. mediterraneus	207	Zannichellia palustris subsp. palustris
28	Carlina curetum subsp. orientalis Meusel & A.Kástner	73	Xanthium spinosum subsp. spinosum	118	Lathyrus oleraceus subsp. oleraceus	163	Salvia spinosa subsp. spinosa	208	Zannichellia palustris subsp. pedicellata (Rosén & Wahlenb.) Arcang.
29	Carlina sicula subsp. mareotica (Asch. & Schweinf.) Greuter	74	Xanthium strumarium subsp. brasilicum (Vell.) O.Bo & Vigo	119	Lathyrus oleraceus subsp. pumilio (Meikle) ined.	164	Jasminum grandiflorum subsp. floribundum (R.Br. ex Fresen.) P.S.Green	209	Cosentinia vellea subsp. vellea
30	Carthamus lanatus subsp. lanatus	75	Xanthium strumarium subsp. strumarium	120	Leucaena leucocephala subsp. leucocephala	165	Olea europaea subsp. europaea	210	Potentilla supina subsp. aegyptiaca (Vis.) Soják
31	Carthamus tenuis subsp. foliosus (Boiss.) Hanelt	76	Matthiola longipetala subsp. bicornis (Sm.) P.W.Ball	121	Lotus corniculatus subsp. corniculatus	166	Ludwigia adscendens subsp. diffusa (Forssk.) P.H.Raven	211	Galium canum subsp. canum
32	Carthamus tenuis subsp. tenuis	77	Matthiola longipetala subsp. hirta (Conti) Greuter & Burdet	122	Lotus pedunculatus subsp. pedunculatus	167	Flueggea virosa subsp. virosa	212	Galium spurium subsp. africanum Verdc.
33	Centaurea calcitrapa subsp. calcitrapa	78	Nasturtiopsis coronopifolia subsp. arabica (Boiss.) Greuter & Burdet	123	Lupinus albus subsp. albus	168	Kickxia spuria subsp. integrifolia (Brot.) R.Fern.	213	Kohautia caespitosa subsp. caespitosa
34	Centaurea pallescens subsp. pallescens	79	Raphanus raphanistrum subsp. sativus (L.) Domin	124	Medicago sativa subsp. sativa	169	Veronica anagalloides subsp. taeckholmiorum Chrtek & Osb.-Kos.	214	Lantana viburnoides subsp. viburnoides
35	Centaurea pullata subsp. pullata	80	Sinapis arvensis subsp. allionii (Jacq.) Baillarg.	125	Onobrychis crista-galli subsp. crista-galli	170	Veronica catenata subsp. pseudocatenata Chrtek & Osb.-Kos.	215	Tribulus megistopterus subsp. pterocarpus (Ehrenb. ex Müll.Berol.) Hosni
36	Centaurea solstitialis subsp. solstitialis	81	Wahlenbergia lobelioides subsp. riparia (A.DC.) Thul	126	Ononis natrix subsp. natrix	171	Veronica scardica subsp. africana Chrtek & Osb.-Kos.	216	Zygophyllum propinquum subsp. migahidii (Hadidi) Jac.Thom & Chaudhary
37	Chiliadenus sericeus subsp. sericeus	82	Ceratophyllum muricatum subsp. muricatum	127	Retama raetam subsp. raetam	172	Limonium sinuatum subsp. romanum Täckh. & Boulos		
38	Chrysanthellum indicum subsp. afroamericanum B.L.Turner	83	Calystegia silvatica subsp. silvatica	128	Senegalia mellifera subsp. mellifera	173	Avena sterilis subsp. ludoviciana (Durieu) Gillet & Magne		
39	Crepis sancta subsp. sancta	84	Convolvulus althaeoides subsp. althaeoides	129	Senna italica subsp. italica	174	Avena sterilis subsp. sterilis		
40	Dicoma schimperi subsp. schimperi	85	Convolvulus althaeoides subsp. tenuissimus (Sm.) Ba	130	Sesbania sesban subsp. sesban	175	Bromus alopecuros subsp. alopecuros		
41	Dittrichia viscosa subsp. angustifolia (Bég.) Greuter	86	Convolvulus dorycnium subsp. dorycnium	131	Tephrosia nubica subsp. nubica	176	Bromus hordeaceus subsp. hordeaceus		
42	Dittrichia viscosa subsp. viscosa	87	Convolvulus hystrix subsp. hystrix	132	Tephrosia purpurea subsp. apollinea (Delile) Hosn El-Karemy	177	Bromus japonicus subsp. japonicus		
43	Echinops spinosissimus subsp. spinosissimus	88	Convolvulus siculus subsp. elongatus Batt.	133	Tephrosia uniflora subsp. uniflora	178	Bromus rubens subsp. rubens		
44	Echinops spinosissimus subsp. spinosus Greuter	89	Convolvulus siculus subsp. siculus	134	Trifolium campestre subsp. campestre	179	Calamagrostis arenaria subsp. australis (Mabille) Asch. & Graebn.		
45	Ethulia conyzoides subsp. conyzoides	90	Cuscuta approximata subsp. approximata	135	Trifolium nigrescens subsp. nigrescens	180	Catapodium rigidum subsp. rigidum		

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

Nu	Name	Nu	Name	Nu	Name	Nu	Name	Nu	Name
1	Achyranthes aspera var. pubescens (Moq.) M.Gómez	17	Ceratophyllum demersum var. demersum	33	Euphorbia hierosolymitana var. hierosolymitana	49	Vachellia oerfota var. oerfota	65	Atraphaxis spinosa var. sinaica (Jaub. & Spach) Boiss.
2	Achyranthes aspera var. sicula L.	18	Convolvulus glomeratus var. glomeratus	34	Euphorbia peplus var. peplus	50	Vachellia seyal var. seyal	66	Lysimachia arvensis var. caerulea (L.) Turland & Bergmeier
3	Agathophora alopecuroides var. papillosa (Maire) Boulos	19	Convolvulus oleifolius var. oleifolius	35	Euphorbia petiolata var. petiolata	51	Gisekia pharnaceoides var. pharnaceoides	67	Ranunculus cornutus var. scandicinus (Boiss.) Ziffer-Berger & Leschner
4	Allium roseum var. tourneuxii Boiss.	20	Convolvulus pilosellifolius var. linearifolius Sa'ad	36	Albizia schimperiana var. schimperiana	52	Najas graminea var. graminea	68	Oldenlandia capensis var. capensis
5	Nothoscordum gracile var. gracile	21	Convolvulus pilosellifolius var. pilosellifolius	37	Indigofera coerulea var. coerulea	53	Najas marina var. intermedia (Wolfg. ex Gorski) Rendle	69	Oldenlandia capensis var. pleiosepala Bremek.
6	Bellevalia flexuosa var. flexuosa	22	Convolvulus stachydifolius var. villosus Hallier f.	38	Indigofera colutea var. colutea	54	Teucrium leucocladum var. leucocladum	70	Oldenlandia corymbosa var. caespitosa (Benth.) Verdc.
7	Bellevalia flexuosa var. galalensis Täckh. & Drar	23	Cuscuta approximata var. urceolata Yunck.	39	Medicago intertexta var. ciliaris (L.) Heyn	55	Abutilon pannosum var. figarianum (Webb) Verdc.	71	Oldenlandia corymbosa var. linearis (DC.) Verdc.
8	Atractylis carduus var. angustifolia Täckh. & Boulos	24	Cuscuta brevistyla var. brevistyla	40	Mimosa pigra var. pigra	56	Abutilon pannosum var. scabrum Verdc.	72	Valantia hispida var. hispida
9	Atractylis carduus var. latifolia Täckh. & Boulos	25	Cuscuta palaestina var. palaestina	41	Pongamia pinnata var. pinnata	57	Nymphaea nouchali var. caerulea (Savigny) Verdc.	73	Phyla nodiflora var. nodiflora
10	Atractylis carduus var. marmarica Täckh. & Boulos	26	Cuscuta planiflora var. planiflora	42	Rhynchosia minima var. memnonia (Delile) T.Cooke	58	Coix lacryma-jobi var. lacryma-jobi	74	Verbena officinalis var. officinalis
11	Reichardia tingitana var. tingitana	27	Cuscuta planiflora var. sicula (Tineo ex Engelm.) Trab. ex Yunck.	43	Senna alexandrina var. alexandrina	59	Dichanthium annulatum var. annulatum	75	Balanites aegyptiaca var. aegyptiaca
12	Sphaeranthus suaveolens var. abyssinicus (Steetz) Ross-Craig	28	Ipomoea batatas var. batatas	44	Senna bicapsularis var. bicapsularis	60	Dinebra retroflexa var. retroflexa	76	Tribulus bimucronatus var. bispinulosus (Kralik) Hosni
13	Symphyotrichum subulatum var. squamatum (Spreng.) S.D.Sundb.	29	Ipomoea cairica var. cairica	45	Trifolium fragiferum var. fragiferum	61	Poa diaphora var. diaphora	77	Tribulus bimucronatus var. inermis (Kralik) Hosni
14	Capparis spinosa var. aegyptia (Lam.) Boiss.	30	Cyperus mundii var. mundii	46	Trifolium purpureum var. purpureum	62	Stipagrostis ciliata var. ciliata	78	Tribulus pentandrus var. micropteris (Kralik) Hosni ex Hadidi
15	Capparis spinosa var. canescens Coss.	31	Cyperus polystachyos var. polystachyos	47	Trifolium resupinatum var. resupinatum	63	Stipagrostis hirtigluma var. hirtigluma	1	Fuirena ciliaris f. ciliaris
16	Silene villosa var. erecta Täckh. & Boulos	32	Fuirena pubescens var. pubescens	48	Trifolium stellatum var. stellatum	64	Stipagrostis uniplumis var. uniplumis	2	Salix × fragilis f. vitellina (L.) I.V.Belyaeva

10. Lists

10.1. List of Figures

10.2. List of Tables

10.3. List of Appendices