

Original research

Mapping Potential Sensitivity as a tool for sustainable urban development in Islands: Case study Al-Shaeir Island, Egypt

Seham Mostafa Qutb, Nada Saleh Mohammed*

Lecturer, Environmental Planning Department, Faculty of Urban Planning, Cairo University (Egypt).

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Abstract:

The environmental sensitivity mapping (ESM) tool is a crucial tool to show location of resources and to indicate environmentally sensitive areas, so environmental planner can use it to take decisions about land development response. GIS has opened up new possibilities for integrating interdisciplinary studies and analysis, which are essential for sustainable planning, especially in island planning as a special case. Island ecosystems are highly sensitive and dynamic, facing many natural and human challenges. Therefore, this research presents a tool (ESM) that is designed according to the unique characteristics of the Egyptian islands to achieve sustainability by using GIS. In this paper, suggestions for future land use, development decisions and protection decisions can be taken from the evidence of ES. This study applied to Al-Shaeir Island, which is considered as one of the areas of unique island, and located in the head of the Nile Delta, where the Nile branches into Rosetta and Damian, it represents historical environmental components. In addition, the island faces many economic, social, and construction problems that have led to environmental impacts reflected on the ecosystem. So that, it needs ESM tools for achieving sustainable ecological management in Egyptian island cases.

Keywords: sustainable urban development- environmental sensitivity areas- islands development- environmental sensitivity mapping tool- GIS.

1- INTRODUCTION

Environmental Sensitivity Mapping tool aims to display where different resources are locating and to identify environmentally sensitive areas (Leman et al., 2016; Beisl, et al.,2003) that ecologists may use to respond to emergencies, make decisions about land development and disaster response, and plan and determine the environmental impacts of actual or Hypothetical (Petersen et al., 2019; Blinovskaya, 2005).

The literature review emphasizes the various aspects and components of ESM, as well as the definition of sensitivity. A variety of meanings combine receptor vulnerability with flexibility, indicating that sensitivity refers to the system's ability or inability to deal with negative effects. (Quan et al., 2010).

Corresponding author*: E-mail address: eng_nada20072012@yahoo.com

For planning and decision-making, environmental awareness must provide early notice of potential land use conflicts and recognize the location and nature of potential adverse impacts, or assess them in light of potential problems arising from the implementation of particular sectoral plans and programs, or projects (Bas, 2019). To increase the impact generated by the results, more efforts are required to link research to live projects using clear and easily transferable methods. (Epstein and Selber, 2002; NOAA, 2018; Petersen et al., 2019; Goto et al., 2019).

Such maps may be useful for integrated coastal zone and resource management, where resource assessment is critical not only for coastal and island but also for water areas (Ishtiaque et al., 2019; Shavykin et al., 2018). With regard to the environmental impacts of any natural and anthropogenic influences, the biological and socio-economic services of these aquatic regions should be considered. (Mona, 2006).

1.1. Definitions and Concept of Environmental Sensitivity Areas

Environmental sensitive areas (ESA) or environmentally critical areas refers to areas characterized by biological systems and renewable and non-renewable resources, which need to deal in a different way from the rest of the areas when developing and managing them (Assem,1995) these areas need, careful studies for development, protection and development, which ensure sustainability (NOAA, 1997). Also, this area are places with unique environmental characteristics that need special attention. These places are essential for the survival of diverse and productive plant and wildlife populations. Rare ecosystems, habitats for endangered species, and locations that are easily affected by human activities (Fabiyyi, 2008).

ESA has important natural components of the regional landscape that provide important ecosystem functions and services. Flood reduction, drinking water supply, regional biodiversity preservation, preservation and connectivity of unique habitats and landscapes, and provision of culturally and economically valuable resources and opportunities are among them (CMRB ,2019).

ESA in Egypt located in several environments (desert - coastal - reserves - rivers - Nile islands ...), and some of these areas may be reserves by decision of the state, but there are other natural areas that need careful environmental study and planning to be managed .The Nile islands in Egypt are considered one of the most promising areas for comprehensive development and eco-tourism, in particular, due to their distinguished geographical location and the diversity of their natural, terrestrial and environmental resources. However, they suffer from many environmental issues. Therefore, it is necessary to prepare maps of environmental sensitivity to be managed sustainably. Identification and assessment of potential ESAs is an important part of the region's long-term development.

The Nile of Egypt contains about 200 islands, many of which appeared after the construction of the High Dam and many of them disappeared when the level of the dam lake rose. Prime Minister Decree No. 1969 of 1998 was issued declaring 144 islands as nature reserves, including 95 islands in Upper Egypt, with a total area of 32,500 acres, and the Rashid branch contains 30 islands with a total area of 3400 acres, and the Damietta branch contains 19 islands with a total area of 1250 acres (EEAA, 2008).

Despite the ecological importance of the Nile islands and the biological importance of most of them for fish, plant wealth, the possibility of cultivating developed varieties of rare crops and plants, converting most of them into centers of conservation and environmental development, The Nile islands suffer from many human environmental problems, including environmental

pollution and the consequent damage to human life. The deterioration of the surrounding environment, problems related to agriculture and the change that affected agricultural activity, whether negatively or positively, the problem of isolation and the deterioration of transportation and communication, which resulted in the occurrence of other problems (Heba,2014)

In 2005, the Egyptian Ministry of State for Environmental Affairs issued a study entitled Towards a National Strategy and Action Plan for Ecotourism in Egypt, in which it stated that the state has adopted a policy of protecting wildlife and marine life by declaring protected lands and areas to care for rare and endangered species and plant species, and to preserve unique geological formations. And the original natural and cultural heritage, in addition to developing, and managing these resources on scientific and technical foundations and rules, regulating their exploitation for developmental, tourism, technical, research and recreational activities to be a renewable source of national income, a valuable heritage And a valuable heritage preserved for generations and a strategic reserve of the country's natural resources, then the strategy indicated that it protects the habitats of resident and migratory birds, develops fish wealth, helps local communities and encourages eco-tourism (EEAA, 2005).

1.2. Criteria and techniques of ESM

Previous studies have indicated two sets of assessment elements for environmental sensitivity areas , the first group that Represented in (size, nature, scarcity, sensitivity, typicality, historical records, environmental status or geographical unit, expected value, demand on the site), the second group which the elements are (the uniqueness and difference in the shape of the earth, the importance and vitality of the ecosystem, plant and animal life, biological diversity, scarcity, aesthetic and visual values, connectivity, fragility, landscapes, space(Ehab and Mona,2012; Souza, et al ,2004; Wiczorek et al., 2007)

The research has identified and selected a group of elements and criteria for the environmental classification of the Nile islands, listed according to the environmental values from (Biodiversity Scarcity-Fragility-Naturalness-Aesthetics-History-Cultural Value-Connectivity), taking into consideration the uniqueness of the status of the Nile Islands with its environmental characteristics.

The criteria for assessing the environmental sensitivity of the Nile islands with distinct components have an important role in the protection and preservation of natural habitats, whether it is plant and animal life, a group of terrain or picturesque areas. With the help of environmental sensitivity assessment criteria, it is possible to determine the levels of environmental sensitivity for each of the areas to be developed for the purposes of development. The levels of environmental sensitivity are graded to several levels. The levels of development are determined for sustainable urban development urban development, environmental conservation areas and abandoned areas as shown in figure (1)

Environmental sensitivity mapping has been effectively supplemented using the GIS tool. As a map-based technique employing GIS, most current research in this field uses degree of sensitivity.

Research mainly focuses on discussing the Environmental Sensitivity Mapping (ESM) as a tool to making decisions related to the localization of uses and the procedures for the urban development and preserving natural resources using GIS.

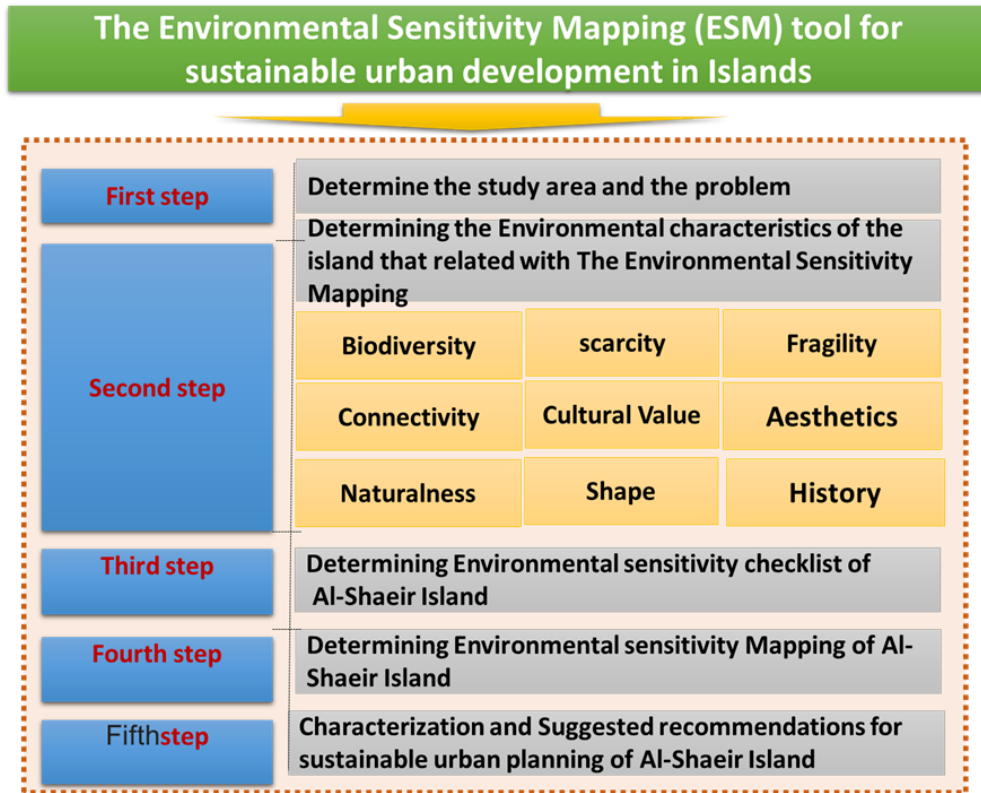


Figure 1: practical framework

2. MATERIALS AND METHODS

2.1. Environmental sensitivity mapping tool in the Egyptian Nile Islands: Al-Shaeir Island case study

2.1.1. Introduction to the Study Area

Al-Shaeir Island is distinguishing by its location, which is the head of the delta, at which the Nile branches into Damietta and Rosetta as shown in figure (2) (GOPP, 2008), and the island is distinguishing by its fertile agricultural lands, which represent more than 80% of the total area of the island, as well as it is famous for the existence of garden areas and the spread and diversity of plants (Gopp,2017) Al-Shaeir Island is considering one of the Nile River Islands, which is located in the Qalyubia Governorate, specifically, as it is the head of the delta, and then the Nile branches into Damietta and Rosetta branches, administratively affiliated with the city of El-Qanater El-Khayriya.

The area of the island is about 600 acres, of which about 10% are a block of housing, where about 20 thousand people live (Kamal, 2012), and the rest are agricultural lands (GOPP, 2017). Activities affected the environmental values on the island, so the following figure shows the morphological change on the island. From a comparison of the morphological changes that occurred on the island's body from 2004 to 2021, some cover sites disappeared and urbanization developed within the island. These areas turned into human activities that mainly represented in agricultural activity and some urban scattered areas as shown in figure (3).



Figure (2): Location of Al-Shaeir Source: Gopp,2021

Human activities, existing and future urban growth, as well as the primitive methods used in agricultural activity on the island and the use of pesticides and others, the effect of all of this on the System and components of agricultural lands, which lost part of its vitality and health.

Although human activities and the island's enjoyment of recreational and tourism activities based mainly on its garden area, which enjoys a tremendous diversity of plant life and trees, the lack of awareness of its importance among people has led to a clear environmental deterioration of areas with plant life, and this is due to the lack of awareness and monitoring that led to the loss of rare and old types of trees as a result of unjust withdrawal in cutting them, such as the old trees in them, the loss of diversity and trees in the regions, which led to an imbalance in the systems and their vitality and the impact on the aesthetic and historical values of those ecosystems.

Hence, the importance of paying attention to ecosystem sensitivity on the island, which is considered one of its most important components, spreading awareness of their importance and the need to preserve them, as well as relying on high and employing them for economic activities in line with their nature that enables access to the vitality of ecosystems as well as ensuring healthy ecosystems and thus reaching the island's environmental sustainability.

2.1.2. Environmental characteristics of the island

Al-Shaeir Island, the most important environmental characteristics of the island can be monitored, represented by the following elements:

Environmental characteristics that will be studied have been determined by a map of the environmental sensitivity of the islands and prepared based on theoretical readings, in addition to conducting a field survey to determine the appropriate elements for the Egyptian case.



Figure (3) The urban development and change of its shape of Island in 1994, 2021

The main aim of the survey is to establish significant Environmental characteristics for the environmental assessment using the Environmental Sensitivity of Egyptian islands as an aspect in prioritizing and aiding in decision-making policies, a list of 10 specialists are selected to determine the most environmental characteristics that should be studied. The list consists of experts in preserving and managing islands at GOPP, staff members of the Faculty of Regional & Urban Planning interested, the worker in the field on cultural heritage, and finally and a member of Egyptian Environmental Affairs Agency. In the following, those characteristics of the island under study.

a- vegetation cover and biological diversity in Al-Shaeir Island

Figure (4) show that Al-Shaeir island is a permanent island with an environmental sensitivity as island that subjects to change by natural or human factors, therefore these variables must be considered when preparing development plans for the island, and wetlands are considered one of the fastest geological formations to the disappearance and the age of the island is considered A quick moment concerning the age of the earth hence the protection of wetlands is essential to protect nature and the ecosystem.

Since island is considered one of the wetlands, it contains agricultural land by up to 80%, is surrounded by water on all sides, contains biological diversity of plant and animal life, it works as a natural reservoir for groundwater, and it contains pollutants but the cover The vegetarianism it contains represents a large proportion of the island that helping to reduce climate changes

Studies indicate that the island represents the home and complex of many types of natural plants, vegetation cover, and trees where the abundance in vegetation cover and environmental diversity in Al Qanater Charitable Gardens is about 130 species belonging to 90 plant genera, and plant species are represented in all gardens There are 4,392 individuals among trees, shrubs, and climbers, as well as 20 acres of various medicinal and aromatic plants in Al-Shaeir Island.

There are rare animals on the island, as it contains 5 rare breeds of goats, the best of them being fallow goats, as well as the presence of a crocodile bird, and that of course it is one of the agricultural islands, and there are 6 plant and animal farms (fish farms belonging to the Water Research Institute, an area of 5 acres. Farms belonging to the Horticulture Training Center of the Ministry of Agriculture with an area of 20 acres and containing apiaries - Animal Production Farm area of 28 acres - Central Administration Farm for stations and has a livestock farm area of 90 acres - Medicinal and Aromatic Plants Propagation Farm of an area of 20 acres.

B-Biodiversity

Biodiversity is one of the most important elements of environmental sensitivity because of its role in the stability and stability of the system and because it contains services of its own. Hence, it gives great returns and benefits. Biodiversity represents all the existing organisms of live plants and animals that exist in the current situation or have become extinct, the island's biological diversity is represented by the plant life in its 130 species belonging to 90 plant genera, and the plant species in all gardens represent 4,392 individuals between trees, shrubs and climbers. As well as the presence of 13 acres of different medicinal and aromatic plants, as well as a group of rare animals, which contains 5 rare breeds of goats, the best of them being the Po goats. As well as the presence of a cattle egret, which of course is one of the agricultural islands and there are 6 plant and animal farms in it fish farms belonging to the Water Research Institute, an area of 5 acres — farms belonging to the Horticulture Training Center of the Ministry of Agriculture, an

area of 20 acres with apiary — the animal production farm area 28 acres - the farm of the central administration of the stations and it has a livestock farm of 90 acres — a plant for propagating medicinal and aromatic plants ,and an area of 20 acres as shown in figure (5).



Figure (4) Vegetation cover and biological diversity

c- Shape of the land

The monuments and natural resources consider influencing the formation of the land through the surrounding features, such as the presence of the Nile River from all directions and the island's position as it represents the head of the delta.

All of these factors affect the formation of the island and take it the longitudinal shape as it is considered one of the permanent islands, and the analysis with satellite images shows that the barley island still maintains its shape in different aspects of it and not the shape of the island itself.



Figure (5) Biodiversity in Al-Shaair Island. Source: GOPP, 2021

topography of the governorate generally descends gradually from the south to the northeast, as the surface of the governorate is flat except for the eastern edge, and therefore the island is

considered the flat part of the governorate, as well as the maximum height inside the island reaches 30 meters and most of the island is considered to have flat to semi-flat tendencies as shown in figure (6).

It is evident from the preliminary results that the island land, in general, is loamy loam, fertile for agriculture, and its tendencies are flat. Topography has shown that it rises above the surface of the Nile by about 12 meters, which makes it one of the permanent islands.

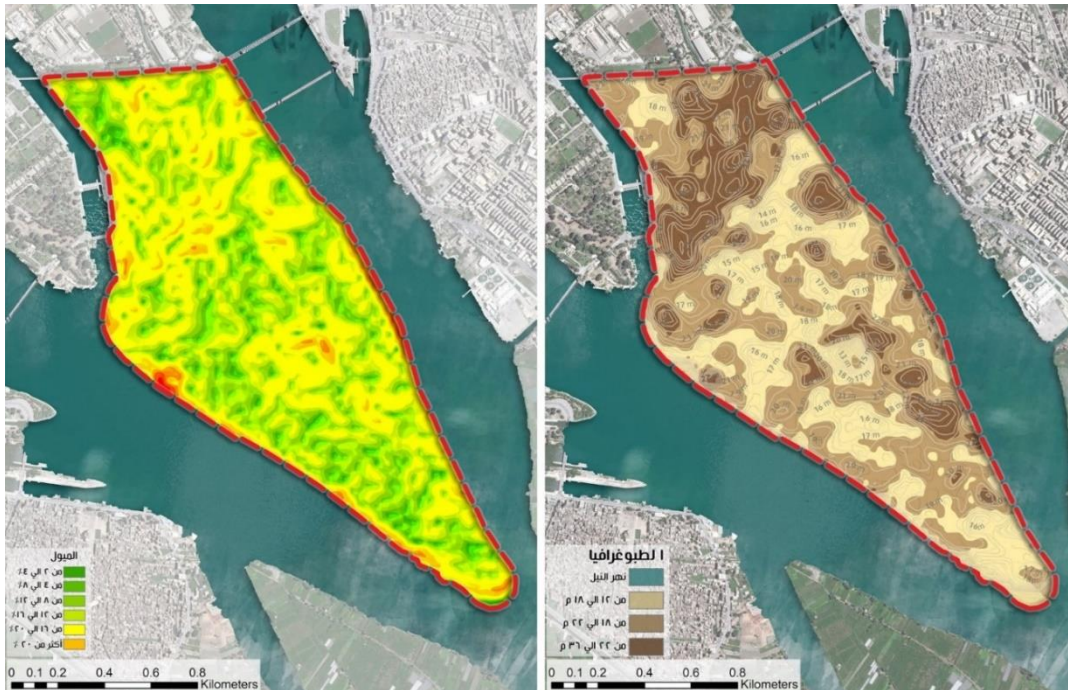


Figure (6) The topography and trends of the island

D. Scarcity vegetation cover and biological diversity

Scarcity consider one of the most important elements of sensitivity, but it is considered one of the basic elements because it works to measure the extent of the scarcity of these species and thus gives a comparative advantage due to the presence of these species and thus gives a comparative advantage to

This range, and it has to deal with it completely different from the other domain and al-sheair Island studies. The Island holds a rare plant and animal life that needs preservation, such as archaic trees and fallow goats.

E. Fragility

The fragility component expresses the extent of the impact of human activities and natural changes on the ecosystem and thus expresses the sensitivity of this region.

The fragility appears on the island in the areas near the edge of the island and is located on the Nile River, due to the variety of plant life contained in these areas as well as through the influence of human activities and influence. Passive on the Nile River through activities too.

F. Natural properties of the site Naturalness

The natural characteristics of the site express the natural areas and systems that are made by the Creator and do not enter the human being,

They also express the sensitivity of the areas greatly as they are areas that must be protected and employed in a manner that suits their nature.

G. Aesthetics

With the intent of aesthetic values, natural uniqueness and natural areas with aesthetic features. AL-sheiar Island enjoys the height of the aesthetic mouth because it contains plants, trees, and garden areas, all of which give a unique aesthetic character.

H. Recorded History

figure (7) show that, Historical values must be protected because of their importance and value, as they give regions a distinctive nature of their own. And found on the island a group of historical areas that distinguish it, such as the Qanater Charitable Gardens, the Children's Museum of Water Sciences, and each of them has its own nature, characteristics and features of its own history.



Figure (7) The Historical values of the island Source: GOPP, 2020

Cultural Value

It refers to the regions and evaluations that have a cultural impact that must be preserved because of the importance of these values. Al-sheair Island has various cultural values from museums, institutes of studies, and recreational areas with different historical values, which give each of them a high economic return as shown in figure (8).

Environmental methods must be required to rehabilitate them and to settle development activities because of their high social and economic return.



Figure (8) The Cultural Value of Al-Shaeir Island Source: GOPP, 2020

J. Connectivity, accessibility

Al-Shaeir Island is highly connected to the surrounding area through the commonly used traditional means of movement such as cars and others.

2.1.3 Environmental sensitivity checklist of Al-Shaeir Island

The environmental assessment of Al-Shaeir Island was prepared by a checklist to assess the environmental sensitivity criteria on the island

Through environmental studies, the help of a field visit to the island, and a questionnaire for the population and stakeholders. It is explained in table (1)

Table (1) The environmental sensitivity checklist of Al-Shaeir Island

Element	Range		The description
Biodiversity	Flora	✓	The island contains a tremendous biodiversity of flora and fauna
	funa	✓	
Scarcity	High value	✓	The island is characterized by a high value of scarcity due to the fact that it contains animals and plants such as fallow goats and ancient trees
	Medium value		
	Low value		
Fragility	Fragile	✓	The island is considered a fragile island that can have problems, but after some time it can return to what it is
	non		
Naturalness	Pure naturalness		The island is characterized as having completely natural values, but it also contains man-made ingredients
	Semi naturalness	✓	
Aesthetics	High value	✓	The island has a group of gardens that are characterized by aesthetic values that make it a high value of aesthetics
	Medium value		
	Low value		
History	Have history	✓	The island contains a group of historical buildings such as the Irrigation Museum and the Children's Museum
	No history		
Cultural Value	High value		The island is characterized by a high value of cultural value represented in the areas of gardens and history
	Medium value	✓	
	Low value		
Connectivity	Possible	✓	The island is easily accessible as it is surrounded by roads and bridges that connect to it
	moderated		
	Not possible		

2.1.4. Environmental Sensitivity Mapping

The boundaries between the environmental sectors were determined based on development boundaries that consider the environmental criteria that will affect decision-making. A group of elements that have an impact in determining the environmental values of the sensitivity values were relied upon, such as the main environmental characteristics (such as the topographic map, the tendencies map, the soil map, the biodiversity map, and the values map). The cultural and historical map, in addition to the map of agricultural lands, green areas and road map), and the

GIS program was used to compile all these maps to reach the environmentally homogeneous environmental sectors, and each environmental sector was described regarding environmental sensitivity characteristics to guide the proposed urban development.

Benchmarking shells have been prepared in order to assess the environmental sensitivity of the island through the multi-criteria spatial assessment model (MCAM), which is considered one of the most important models for applying spatial planning. The evaluation was done from 5 for each of the criteria of the criteria for its presence, it is expressed from 1 to 2 as a weak degree, 3-4 to a medium, and 5 and the sum of each criterion then divide by the total as effectiveness for the total expression of the degree of sensitivity for each as shown in table (2).

It is evident through the assessment that the island has a high value of biological diversity, natural characteristics, aesthetics, and some areas of the island have a sensitivity rate of .94% and are considered areas of high environmental value.

The Environmental sensitivity mapping addresses (zone a) as not suitable for urban development due to its high scale of sensitivity compared to other sectors (94%), as it contains a tremendous diversity of plant life.

In this range, it also contains the rare species of nature, it is also one of the areas of picturesque nature, so it refers to the high cultural value of such as the Muhammad Ali Bridge, gates and arches.

Table (2) Environmental sensitivity assessment by using McA

	Biodiversity	Scarcity	Fragility	Natural properties	shape	Aesthetics	History	Cultural Value	Connectivity	Actual total	Weight
A	5	3	3	0	3	5	3	3	2	32	.0914
B	5	3	3	0	3	5	3	4	2	33	.094
C	3	2	2	4	2	3	2	1	2	24	.068
D	4	3	3	5	3	5	3	4	2	32	.0914
E	3	2	2	3	3	4	2	2	1	22	.062
F	4	2	2	4	4	4	2	2	2	26	.074
G	3	2	2	4	3	5	3	3	2	27	.077
H	3	2	2	4	3	4	2	2	1	23	.065
I	3	2	2	4	3	4	3	2	2	25	.071
J	3	2	2	4	3	4	2	2	1	23	.065
K	4	2	2	4	3	4	2	2	2	27	.077
L	3	2	2	3	3	4	3	2	2	24	.068
M	0	3	3	5	3	5	3	3	2	32	.0914
TOTAL										350	1
X	The Nile River perimeter prevents construction on it from a distance of 30 meters from the Nile line										
Y	Developmental determinant of "chair break"										

The paper addresses sector (E) as the most suitable for urban development due to its low scale of sensitivity compared to other sectors (0.62), due to the existence of built-up areas to contain residential activities, and due to environmental original conditions as it contains plant life, but it is limited to small plants and some plantings only and also does not contain rare creatures, therefore it is more suitable for urban development and human activities in this rang. So the low sensitivity is a result of already existing urban development making more developments will have negative impacts on its sensitivity scale as shown in figure (9).



Figure (9) Environmental sensitivity mapping

3. RESULTS AND DISCUSSION

Characterization and recommendations for sustainable planning of Al-Shaair Island:

In this step, the characteristics and components of the environmental zones and urban sectors are clarified recommendations and suggestions for future urban development according to the characteristics of each zone for achieving sustainability (Table 3)

Hence, the environmental assessment using Environmental Sensitivity helps in making decisions related to the localization of uses and the procedures for the stages of planning processes in a manner suitable for and preserving natural resources.

The land of the island in general is loamy, fertile, suitable for agriculture, and its tendencies are flat. Topography has revealed that it is above the surface of the Nile River by about 12 m, which makes it one of the permanent islands, and we conclude from this the island's validity to establish various activities and uses.

The island also has a high value of biological diversity, natural characteristics, aesthetics, some areas of the island have a sensitivity rate of 87%, and they are considered areas of high environmental value, up to 59%, so those areas are the most suitable for urban development.

Table (3) Characterization and Suggested recommendations for urban development of Al-Shaeir Island

Zones	Characterization	Suggested recommendations
A	Areas of biological diversity (home to some seasonal birds such as the white plush and the gull) Variety in the vegetation, as there is a blank garden Unique natural and aesthetic values and some instances of innate life	Areas of high environmental value where it can take advantage of areas and landscapes in the process of tourist attractions, such as the inattention garden Making tourism development to raise the spatial value and maximize the material return, taking into account environmental requirements
A	Distinguished aesthetic and visual values Biodiversity (seasonal birds marine life)	Areas of environmental value Taking advantage of the natural and aesthetic landscapes in creating, preserving and developing tourism paths, taking into account the environmental dimension
B	Constructed urban areas, (housing villas) Special uses in addition to agricultural pockets	Stable areas of urban development Making use of the vacant lands in the resettlement of tourism services
C	An area characterized by a high biological diversity High aesthetic value Rising cultural and archaeological value - Children's Museum of Water Sciences	Environmental conservation areas Science Museum (archaeological area)
D	Existing urban areas - agricultural lands	Stable areas of urban development Making use of the vacant lands in the resettlement of tourism services

Zones	Characterization	Suggested recommendations
E	Agricultural lands with high productivity	Areas of economic importance Can be relied upon in the export of plants and the local tourism development
F	Marjanah Village is of high aesthetic and recreational value	Abandoned areas (suitable for urban development) Development of the village to increase tourism absorption and bring in a higher material return due to its aesthetic value and its distinguished location
G	Housing, villas, and agricultural lands	Stable areas of urban development Making use of the vacant lands in the resettlement of tourism services
H	Existing urban areas - agricultural lands	
I	Existing urban areas	
J	Agricultural lands with high productivity	
K	Urban Areas List (Housing Villas)	Environmental conservation areas Irrigation Museum (archaeological area)
L	A high archaeological value is due to the Irrigation Museum	
M	High biological diversity Variety in vegetation as it has the model garden and flowerbed Unique natural and aesthetic values and some instances of innate life	Areas of economic importance Can be relied upon in the export of plants and the local tourism development
X	The Nile River perimeter prevents construction on it from a distance of 30 meters from the Nile line	
Y	Developmental determinant of chair break	

4. CONCLUSION

A sensitivity assessment is one of the important tools for understanding the naturalness of the area and the natural resources it contains, which helps specialists in making decisions related to the area because it contains a set of elements of nature that works on their careful study to reach a set of decisions such as (biological diversity - scarcity) Fragility - Aesthetics ... and other characteristics.

- Understanding the natural characteristics of the region and determining the natural capital that characterizes the geographical area
- Identifying areas rich in natural resources and representing areas of high sensitivity

- Determine the appropriate uses for the zone based on its natural components and employ them for economic and social purposes
- Setting guiding steps to protect areas with high sensitivity

To achieve environmental sustainability, in general, at the island level, a set of criteria must be met, which are Sustainable resource management, traditional knowledge, Ecosystem services, Invasive alien species, and Genetic Resources.

To achieve environmental sustainability, especially at the level of Al-Shaeir Island, it is necessary to consider the importance of the vitality and health of ecosystems.

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