Using Remote Sensing and GIS Application for the Development of Aquaculture in Nasser Lake

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1. Abstract

Poverty is a socio-economic scourge raging at varying degrees throughout the Arab countries. The general trends that can be identified using aggregate information are useful for evaluating and monitoring the overall performance of Arab world. Poverty refers simply to lack of resources or abilities of households or persons to meet their current needs. This means that poverty relies on the individuals or households resources in relation to their needs. Furthermore the low levels of income, poverty usually involves hunger, illiteracy, epidemics and the lack of health services or safe water. Such multi-dimensional nature of poverty leads to a set of indicators that are used in measuring poverty and so on to analyze it. Poverty measuring and analysis often based on national level indicators that are compared over time. Consequently, a holistic planning, implementation and control process is needed. This should include all layers of government, non-government, donor agencies, and global organizations with the paper community on one hand, and a combination of historical, economical, sociological, and spatial viewpoints on the other hand. The spatial perspective, which is the main objective of this paper, using spatial technologies have benefited the poor people mostly indirectly, by generating improved information for research, policy analysis, planning, and monitoring. The researcher illustrates the options and limitations of using disaggregated poverty maps for targeting pro-poor aquaculture development. The researcher review the current state of the science with respect to GIS and remote sensing applications in Nasser Lake for aquaculture, including site location, aquaculture facility mapping, market proximity analysis and associated roadway infrastructure, epizootic mitigation, meteorological event and flood early warning, environmental pollution monitoring, and aquatic ecosystem impact, primarily for Nail tilapia and Catfish. Also the potential of technology transfer from the fisheries research centers in Egypt. The potential for multi-sensor remote sensing deployment to support

sustainable fish production in these environments and subsequently in other African countries is evaluated.

Keywords: Aquaculture, GIS, Nasser Lake,

2. Introduction:

Nidhi Nagabhatla.et al. (2015) identified the Aquaculture, mainly referring to the farming of fish and shellfish, forms a major enterprise in the primary production sector in the inland, freshwater, brackish water areas.

Aquaculture is one of the fastest growing food production systems in the world. The fisheries sector occupies an important place in the socio-economic development of the country. It has been recognized as a powerful income and employment generator and is a source of cheap and nutritious food besides being a foreign exchange earner. Most importantly, it is the source of livelihood for a large section of economically backward population of the country (Ayyappan and Krishnan, 2004). To meet the minimum protein requirement of the ever-increasing population of the country, the fish production needs to be enhanced. The inland aquaculture sector has a great scope to meet the demand of the nation. The success of aquaculture is dependent on the site that has suitable qualities of soil, water and infrastructure facilities (Ashok K. and other 2014).

It is important to note that issues in aquaculture have two main sources: those stemming from aquaculture itself and those that affect aquaculture owing to external activities or events. No matter what the origin, each of these issues possess a number of components that vary by location and, therefore, can be addressed by spatial analyses. In this regard, GIS and remote sensing have been used to address the **"what, where and how?"**.

Geographic information systems (GISs) can serve to promote aquaculture by providing an analytical and predictive means for development, management and testing of development consequences.

GIS has been used in aquaculture since the mid-1980s. Meaden and Kapetsky (1991) combined several of the earliest case studies in an FAO technical paper along with complete information on the use of GIS and remote sensing in inland fisheries and aquaculture.

These include the use of remote sensing and, GIS for Nail tilapia and catfish farming development by mapping and analyzing the physical characteristics of soils, and to find where the best opportunities for fish farming in Nasser lake.

Another early study conducted by Kapetsky In 1994 continued his studies suggested the criteria necessary for using GIS and its applications to aquaculture to determine the warm water fish pond farming potential in Africa.

Studies also have included both developing (Kapetsky, 1994) and developed countries. Despite the increasingly frequent applications, specific tools and methodologies for achieving the goals are still under development (Pérez et al., 2003).

3. Paper Aims

The main thrust of this paper is to provide measures of the status of GIS as it is employed to address spatial issues in the development and management of aquaculture. So this paper involved the production of GIS to determine potential aquaculture sites in the Nasser Lake. The analytical work consisted of the determination of evaluation criteria for freshwater fish farming using inland ponds based on: water quality, quantity and availability; proneness to flooding; soil type; topography; land use/cover and infrastructure and development of GIS application for aquaculture siting (Kapetsky, J.M. Hill, and D. Worthy,1988).

And to help in making authentic decision, which are purely based on ground realities and can be used for scientific in-hand information for exploring the suitability towards aquaculture development.

4. Materials and Methods

4.1. Study area

Nasser Lake is a reservoir in the course of the Nile river formed as a result of the construction of the Aswan High Dam. It is located at the border between Egypt and Sudan between latitudes 21.8 to 24.0°N and Longitudes 31.3 to 33.1°E. Its surface area is about 5248 Km2 with a maximum capacity of 165 km3 and mean depth of 130 m, its surface elevation is 175m (UNE, 2015). The lake is circa 550 km long (more than 350 km in Egypt and the rest in Sudan) and 35 km across at its widest point. It plays a main role in the local and national economy. That is reason why the water levels are accurately controlled.

Figure 1 : Location map of Nasser Lake

The southern sector of Aswan governorate is located Lake Nasser area on the other hand with 73% of the Aswan governorate land area, has a wealth of resources including huge tourist potentials, extractive and mineral resources, fishing activities and above all water abundance from the lake that can be used for irrigation and reclamation of land. This sector currently has less than 1% of the population (CAPMAS, 2006). The irregular and huge fluctuations in water-level of the lake, poor soils, steep shoreline and inaccessibility are some of the factors that have led to the failure of almost all development efforts along the lake shores. Vegetation and fishing varies greatly with fluctuations in lake-level, one meter increase in the water level could expand the shoreline for six kilometers.

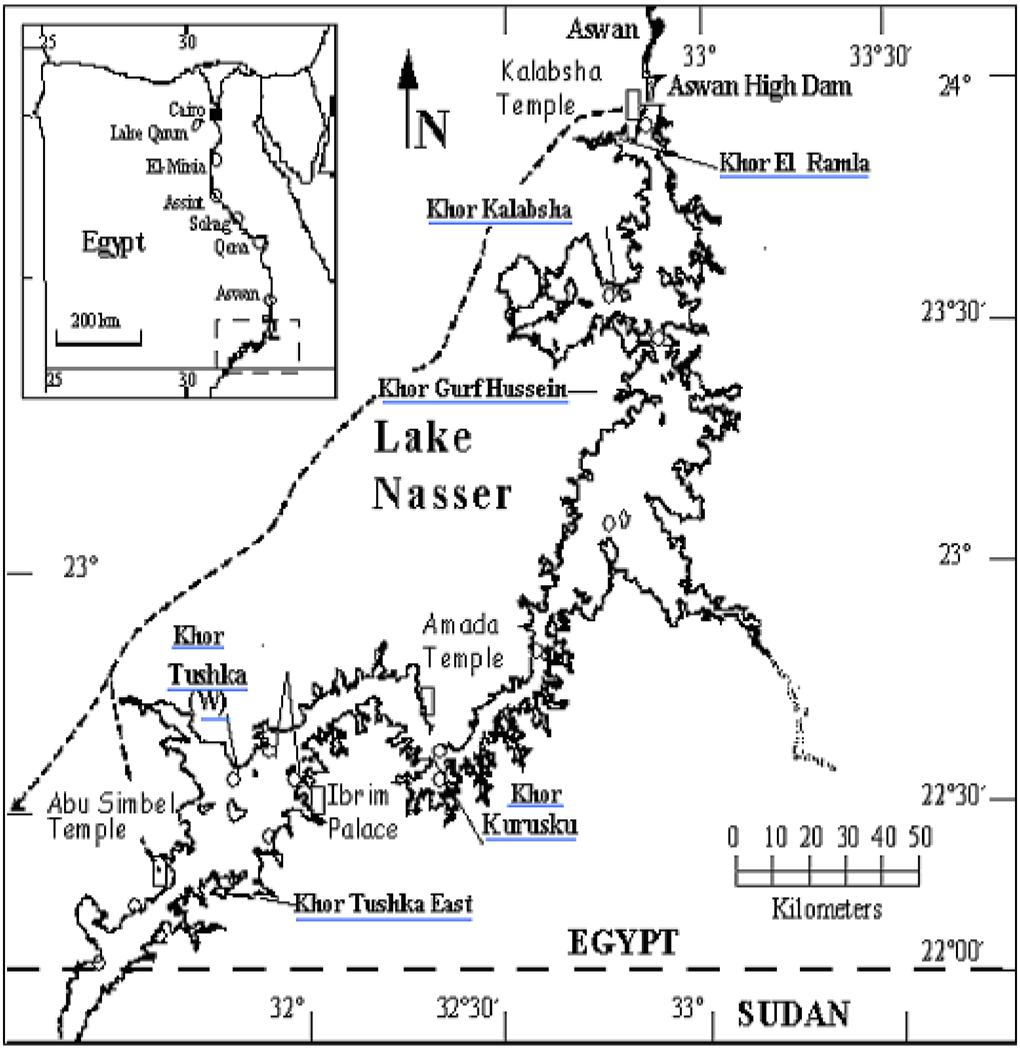

Figure 2 : Map of Nasser Lake

Nasser Lake is the key of strategic importance for sustaining Egypt's water demand and it is essential that its water quality is protected from pollution. It is a vital importance and the main reservoir of fresh water for Egypt. Nasser Lake and the adjacent region are mainly considered as the future food security for the country. To the east of Nasser Lake are the elevated mountain ranges of the Eastern Desert divided by dry valleys concurrently to the west is the low lying sandy Western Desert.

4.2. Study Boundary.

Whereas the Satellite images of Nasser lake band 7 (Spatial Resolution) aren't available at the Geographic Information System department of the CAPMAS. Then the paper completed his study to determine a potential aquaculture sites in the Nasser Lake as a proposed model by exploring two methods can be used for predicting that aquaculture sites.

4.3. Methodology.

The methodology of this paper is highly dependent on the concepts used, the methods selected and the data available. The selected methods should be based on an evaluation of the techniques available in spatial analysis of GIS. There are two techniques for proposed modeless in this paper will discuss below:

1. Proposed Model Balding based-ANN.
2. Proposed Model Balding based-MCE.

4.3.1. Proposed Model Balding based-ANN:

Application of remote sensing (RS) in aquaculture includes land/water use patterns, suitability classification and resource use zoning (Burrough, 1986). A use of GIS incorporates efficient storage, management and analysis of spatial and non-spatial data. Collectively, RS and GIS can served as analytical and prediction tools for planning of aquaculture development and to test the consequence of various development decisions before they are applied in the landscape (M.Shahadat. and N.GopaL Das, 2010).

The first method that can be used for exploration suitability of areas for aquaculture development in Nasser Lake was assessed by establishing which factors and constraints were important, and how they would impact. A factor is defined as a criterion that adds to or detracts from the suitability of the specific alternative under consideration, while a constraint serves to limit alternatives under consideration (Eastman, 2001). Examples of constraints considered in this paper are road networks, river courses and large water bodies (in relation to pond construction). Factors considered basic for aquaculture development were; water availability and quality, terrain and soil suitability, infrastructure in the form of roads, support in the form of extension services and supply of fingerlings, availability of inputs (manure, agriculture by-products and other feed types) and markets.

The factors were classified in four suitability rankings i.e. very suitable (VS), suitable (S) fairly suitable (FS) and unsuitable (US). The VS level provides a situation in which minimum time or investment is probably to be required in order to develop fish farming, an S classification implies that modest time and investment are required, FS implies that significant interventions may be required before fish farming operations can be guided as long as US implies that the time or cost, or both, are too great to be worthwhile for fish farming (Aguilar-Manjarrez et al. 1998).

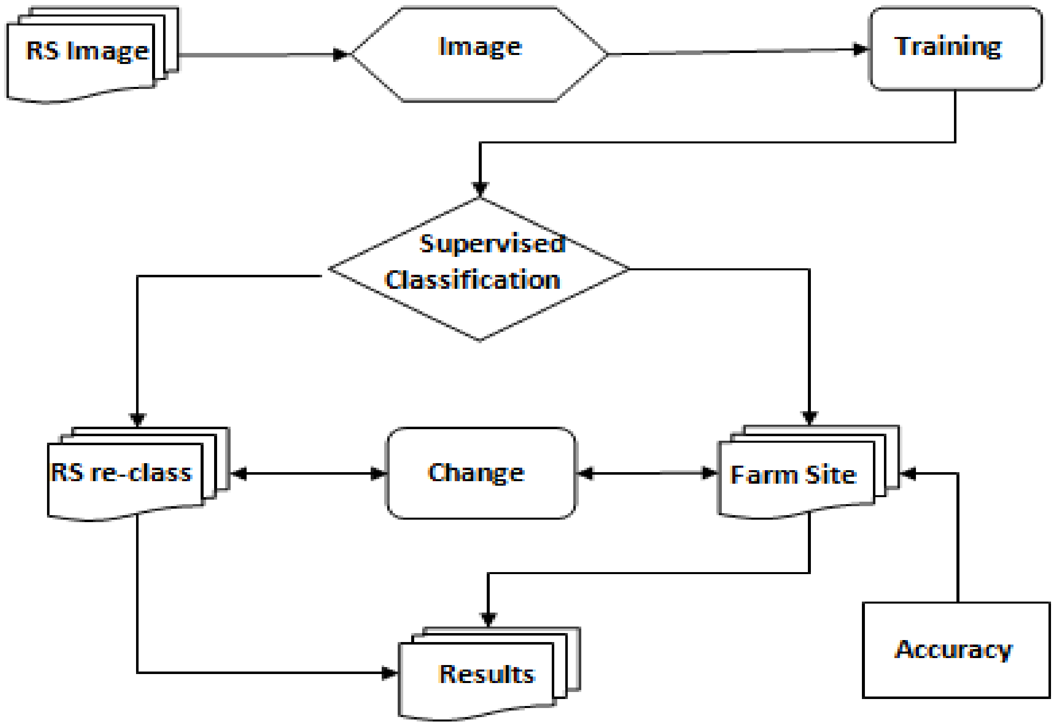

Figure 3: The algorithm of image classification process
Source: Wagdy Ashry, 2013

4.3.1.1. GIS Software and Systems Used

The primary software tools used were IDRISI integrated GIS, Image Processing system providing over 250 modules for the analysis and display of digital spatial information. It is raster based but with vector capabilities.

Scientific examination and classification of water quality, soil characteristics ،topography, infrastructure and socio-economic factors were carried out to recognize suitable areas for aquaculture development. Landsat satellite imagery and 24 thematic layers were analyzed with IDRISI and ArcView software. A GIS models based-ANN was developed to identify and prioritize the suitable areas for aqua farming. The classification of RS model is able to simulate urban development based on current effective variables "criteria". This type of simulation models can be done by using original data directly to train the neural network for generating realistic simulation without planning interference (Wu and Webster, 1998: pp.103–126). Li and Yeh, (2002: 1445-1462).

4.3.2. Proposed Model Balding based-MCE:

The multi-criteria evaluations (MCE) is another concept and model that aid in evaluation by expression in terms of weights, values or intensities of preferences, which ultimately lead to a better decision making. The integration of MCE within a GIS context could help users to improve decision making processes (Hossain et al.,2009). With reference to the altitudinal zones, a few studies have been conducted for aquaculture development in Kumaon region (Tyagi et al., 1999; Tyagi, 2005).

Evaluation criteria of water quality, quantity, availability, soil type, land use/land cover and infrastructure facilities were used for developing suitable aquaculture sites for freshwater fish farming (Girap, 2006).

GIS based on Multi-Criteria Evaluation was used in Hossain and Das's research (M. Konar, et al. 2013) to determine the basis of suitability for prawn farming in Noakhali, Bangladesh.

The objective of this paper is to determine the suitable areas in Nasser Lake for aquaculture through the MCE technique within a GIS context, using Landsat satellite images, water quality data, soil characteristics, infrastructure and socio-economic factors.

The following diagram describe the process we used to generate the map that could be used to guide for a potential aquaculture site in Nasser lake.

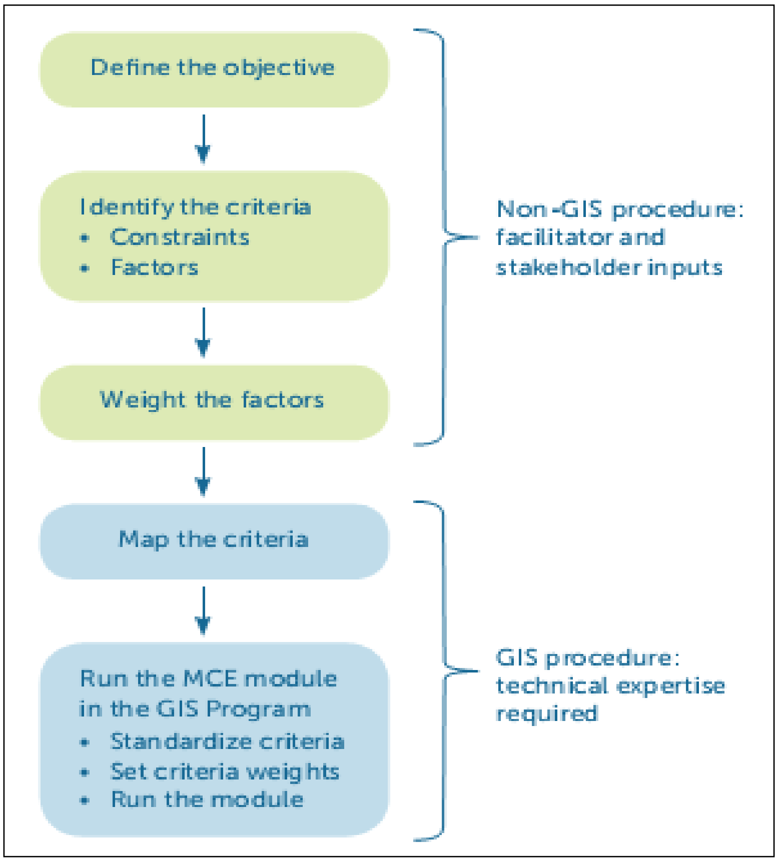

Figure 3 : Generalized Procedure for Conducting a Multi-Criteria Evaluation (MCE) Analysis Using GIS.
Source: (López-Marrero, et al. 2011)

1. The first step in conducting an MCE analysis is to define the objective of the analysis.
2. The next steps are to identify the criteria that will support the stated objective and determine which criteria are more important than others in supporting that objective. There are two types of criteria for MCE analysis: ***constraints*** and ***factors***.
   Permitted in protected areas).
   Factors and constraints can be selected based on existing literature, they can be defined by an analyst, topographic criteria or they can be defined by a group of experts. In this project, we used topographic criteria in order to have the input of aquaculture criteria.

For choosing a suitable site, a number of essential group of factors are need as water quality, soil quality, topography, infra-structure and socioeconomics must be considered for each species and culture system. Therefore, many variables are involved and each must be weighted according to its relative importance with respect to the optimal growth conditions for fish, as well as cost effective production (Hossain et al., 2007).

There are sixty environmental and economic criteria were selected and compiled in table 1. These criteria were of two types: factors and constraints. Ratings for each criterion were employed from 1 to 16. The next step was to establish weighting for each of the factors according to the pair wise comparison matrix of Saaty (1977).

Table 1: A Summary of the Criteria Used for Freshwater Aquaculture

Criteria	Freshwater fish and prawn farming
1. Water temperature (Air temperature)	Growth performance
2. water from annual rain fall, lakes and underground	Water availability
3. water from streams and rivers	Water availability
4. Local market	Economics
5. Inputs from agriculture by products (crop yield)	Economics
6. Roads	infrastructure
7. NGO, Govt. ,Research station and university	Support
8. pH (soil and water	Good growth performance
9. Salinity (soil and water)	Limiting factors
10. Cyclone, flood and draught	Risk factor
11. Winter rain	Not risk
12. Pollution (industries and urban development	Risk of contamination
13. Land use	Available land
14. Agglomeration	Support
15. Elevation	Risk factor
16. Forest, towns, rivers, lakes, roads	Constraints

Source: M. Shahadat Hossain et al. 2008

Using these weighting procedure eight sub model were developed. Finally, three system oriented models were generated (brackish water shrimp, freshwater prawn and fish) by using different combinations and weightings of the modules previously created.

The development of weights is based on a pair-wise comparison matrix. concern the relative importance of two criteria involved in determining suitability for the stated objective. To use that procedure, it is necessary for the weights to sum up to1. Ratings are systematically scored on a 17-point continuous scale from 1/9 (least important) to 9 (most important) (Saaty, 1977) as in Table 2.

Table 2: The relative important of two criteria

Scale	Ranking	Importance
$1/9$	Extremely	Less Important
$1/8$		
$1/7$	Very Strongly	
$1/6$		
$1/5$	Strongly	
$1/4$		
$1/3$	Moderately	
$1/2$		
1	Equally	
2	Moderately	More Important
3		
4	Strongly	
5		
6	Very Strongly	
7		
8	Extremely	
9		

Source: Saaty,1977

involved in the evaluation for carp farming without repetition. The pair-wBased on the study of Aguilar-Manjarrez (1996), the relative ranking of the factors was made before completing the pair-wise comparison matrix. Scores were assigned in rank order according to the number of factors ise comparison matrices developed are shown in Table 2.

Table 3: Example of a pair-wise comparison matrix for assessing the relative importance of different factors aquaculture potential (numbers show the rating of the row).

Factors	Temperature	pH	DO	Transparency	Existing utilization	Weight
Water quality						
Temperature	1	2	3/2	1/4	2	0.15
pH	1/2	1	3/4	1/8	1	0.08
DO	2/3	4/3	1	1/6	4/3	0.10
Transparency	4	8	6	1	8	0.60
Existing utilization	1/2	1	3/2	1/8	1	0.08
Consistency ratio (CR)	*0.0044*					

	Slope	Texture	pH	OM	Weight
Soil quality					
Slope	1	3	3/2	1/2	0.25
Texture	1/3	1	1/2	1/6	0.08
pH	2/3	2	1	1/3	0.17
OM	2	6	3	1	0.50
Consistency ratio (CR)	*0.0000*				

	Distance to road	Distance to electricity	Distance to market	Distance to fry sources	Labour availability	Weight
Infrastructure and socio-economic factors						
Distance to road	1	1/2	3/2	3	1	0.20
Distance to electricity	2	1	3	6	2	0.40
Distance to market	2/3	1/3	1	2	2/3	0.13
Distance to fry sources	1/3	1/6	1/2	1	1/3	0.07
Labour availability	1	1/2	3/2	3	1	0.20
Consistency ratio (CR)	*0.0000*					

	Water quality	Soil quality	Infrastructure and socio-economic factors	Weight
Land use requirement for assessment of site suitability for carp farming				
Water quality	1	3	1/2	0.30
Soil quality	1/3	1	1/6	0.10
Infrastructure and socio-economic factors	2	6	1	0.60
Consistency ratio (CR)	*0.0000*			

Source: Aguilar-Manjarrez (1996)

After computing the weighting procedure the MCE (multi-criteria evaluation) module was run with the sub-models to find out potential sites fish. Once the MCE suitability maps had been created, it was necessary to determine which cells belonged to fish and prawn as well as suitability classes.

4.3.2.1. Mapping the Criteria

To create the a thematic map, a GIS specialist generated a GIS layer for each criterion, whether constraint or factor, recognized in the previous steps. Factors are usually measured and represented geographically on a continuous scale, such as distance from rivers; nevertheless, they can also be categorical, such as type of land cover. Constraints are always Boolean layers (a GIS layer with only two categories, usually having values of ones and zeros), where areas to be excluded from the analysis must have a value of zero, and those to be included must have a value of one.

4.3.2.2. Implementing the MCE Analysis into a GIS

The final procedure to generate the map is to run the MCE module in the GIS software. We used the Idrisi GIS software to conduct the analysis and produce the map. Similar multi-criteria evaluation methods within a GIS environment can be carried out using other GIS software packages. For example, the GIS software ILWIS (Spatial Multiple Criteria Evaluation Tool) and ArcGIS (Weighted Overlay Analysis, LUCIS Model) have similar applications. The methodology described in this publication could also be adapted to be used in other GIS packages.

The resulting map can act as a tool in helping decision makers visualize choices and evaluate suitable aquaculture areas alternatives. One benefit of this type of analysis is that the map produces continuous geographic data, which reflect relative importance, instead of mere “yes or no” binary data, which can limit alternatives and options based on a range of relative importance values shown on the map (Van der Merwe, J.H.; Lohrentz, G. ,2001).

4.4. Conclusion

This paper has focused on the identification of the most suitable and sustainable locations for aquaculture in Nasser Lake in Aswan Governorate. The analysis considered the available natural conditions, existing uses and users of the environment, and the needs of an aquaculture. Identifying suitable and productive sites is essential for the environmental sustainability and economic viability of aquaculture ventures as it considers issues and resolves conflicts between users (and uses) at the planning stage.

We explored two methods deducting our target.

1. ***Proposed Model Balding based-ANN.***

The aim of this method was to develop a model to predict the trend of suitable aquaculture in Nasser Lake using GIS and artificial neural networks. Remote sensing data helped in model calibration by providing a temporal dataset.

The proposed model will help in predicting the trend of a desirable area, thus helping to predict site and avoid ill effects, if any, through planning measures. The study has illustrated the following points:

• The researched neural network model is simple and convenient in application, but can generate very complex features of land use systems. The ANN exhibits robustness by automatically determining the parameter values during the training, which can be directly imported back in GIS for simulating the land use change, thus reducing the calibration time.

• The proposed model has successfully coupled the GIS environment and the ANN. The GIS provides data and spatial analysis functions for constructing the model. Spatial data is conveniently retrieved from the GIS database for calibration and testing of the model.

2. ***That technique based on***

Using MCE and GIS helped us to develop a map showing areas where it is most critical to plan for land uses that can help ensure the ecosystem services, rather than allow urban expansion that has the potential to limit these same services

MCE analysis and GIS provide important analytical tools for land-use planning and decision making. The use of these two practical applications allows the integration of a variety of geographic datasets to produce an output map for a specific purpose. Land uses for other purposes or for site selection for a particular activity can be determined using the tools presented in this guide.

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