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GEOGRAPHICAL ASSESSMENT OF INLAND FRESHWATER FISH FARMS IN THE PROVINCE OF SINDH, A CASE STUDY OF KOT DIJI, DISTRICT KHAIRPUR

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ABSTRACT

Fisheries sector is being neglected that only share 0.4% to GDP of the country. Like agriculture, this sector can fulfill the food demand and strengthen the economy of the country. In Pakistan, agriculture is facing problems of waterlogging and salinity that make the lands unfit for crop production. Land that is not suitable for crop production can be better used for the construction of fish farms.

This research was carried to perform the geographical assessment of inland freshwater fish farms to find out most suitable site for the construction of fish farms in Kot Diji Taluka Sindh. WOM (weighted overlay method),techniques was applied in GIS environment and result showed seven sites that are considered as most suitable locations for fish farms. If these research findings are shared with concerned departments and applied in the field, then the fish farming sector will improve socio-economic conditions of people of the country.

Key words: Barren lands, fish farm, GIS techniques, site selection, spatial analysis, weighted overlay analysis.

Introduction

In Pakistan, agriculture is one of the dominant sectors that contribute about 19.2 percent to country's Gross Domestic Product (GDP) employs 38.5 percent people to national labour force (Gop, 2020-21). It also supplements the food requirement of a whopping 207 million people of the country. However, this sector is facing numerous issues and one of the main problems is waterlogging and salinity that makes the agricultural lands unfit for crop cultivation. Growing population and limited food resources give birth to multiple challenges like low economy, food insecurity, unemployment and poverty. According to United Nations demographic projections, the population of Pakistan will hit 335M in 2050 and it will become world's third most Populous country (Kugelman, 2011).

Pakistan, like other developing countries is facing problem of waterlogging and salinity. Multiple factors like improper or old irrigation system, unlined canals, use of wastewater for irrigation, inappropriate crop pattern, poor drainage system and lack of sufficient knowledge are responsible for the increasing cases of waterlogging and salinity in Pakistan. It is estimated that 50% of world's agricultural lands will be affected by salinity by 2050 (Kumar, *et al.*, 2020). It is believed that about 20% of world irrigated world land is affected by waterlogging and salinity (Ahmed and Ambinakudige, 2023).

Pakistan is having 79.6 M.Ha (Million Hector) total area out of which 22.0 M.Ha is under cultivation and 6.3 M.Ha land is affected by waterlogging and salinity (Khan *et al*., 2022). Barren lands are considered as the piece of land that do no supports crop cultivation. These lands can be used for the development of fish farms. Lands that do not support crop production and growth are considered as ideal lands for fish farming (Chughtai and Mahmood, 2012; El-Gammal *et al.*, 2014). Aquaculture with development of fish farms, can contribute in the GDP of the country (Aslam *et al.*, 2020).

Pakistan is enriched with natural water resources, fresh water and marine water as well as brackish water. In Pakistan, about 60.47 thousand hectares of total areas are consumed by fishponds (Giri, 2017). Indus River and its tributaries are main source of water to agriculture and aquaculture of the country. In Pakistan, Aquaculture is done in all provinces but Sindh and Punjab provinces are its major contributor. In Sindh province, Manchar and Keenjhar lakes, there are other fresh water lakes in Thatta and Sanghar that support the aquaculture. It is estimated that about 6,000 fish farms are currently functioning with average size 5-10 ha that provides employment to 20,000 people in Sindh (Hari, 2018).

There are multiple lands that are facing problems of waterlogging and salinity in Kot Diji area. These lands were only source of livelihood of the local people that currently became useless for them. In most part of Sindh, farmers use canal irrigation system to provide water to their agricultural lands however, canal water bring excessive amount of salts and minerals too. Continuous result of this act change the agricultural lands in to waterlogged and saline lands. Therefore, they prefer their lands to be used for construction of fish farming. According to Chughtai an Mahmood (2012) aquaculture on saline lands is beneficial.

MATERIALS AND METHODS

Study Area

The study area of this research is Kot Diji taluka of district Khairpur that lies about 24 km South of Khairpur taluka (**Fig.1**). It is located on east bank of the River Indus and opposite to Mohen jo daro, largest ancient city of Indus civilization. The geographical extent of Kot Diji is 27°29'17.37 N to 27°10'21.71 N and 68°29'55.09 E to 68°50'0.94 E having 520.0 km² total areas. The total population of Kot Diji is about 348,582 and 670.4/km² density (Gop, 2020-21).

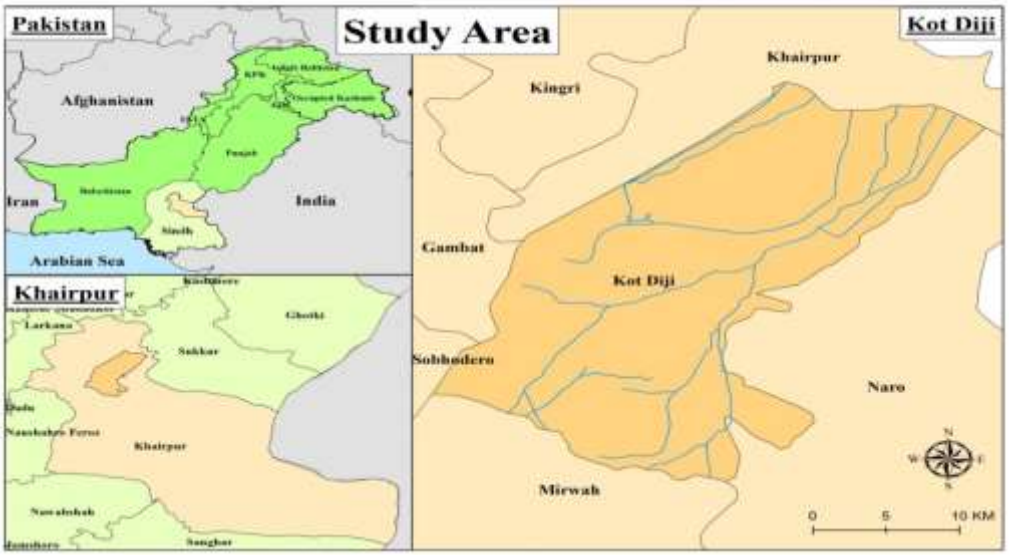

Fig. 1. Study area.

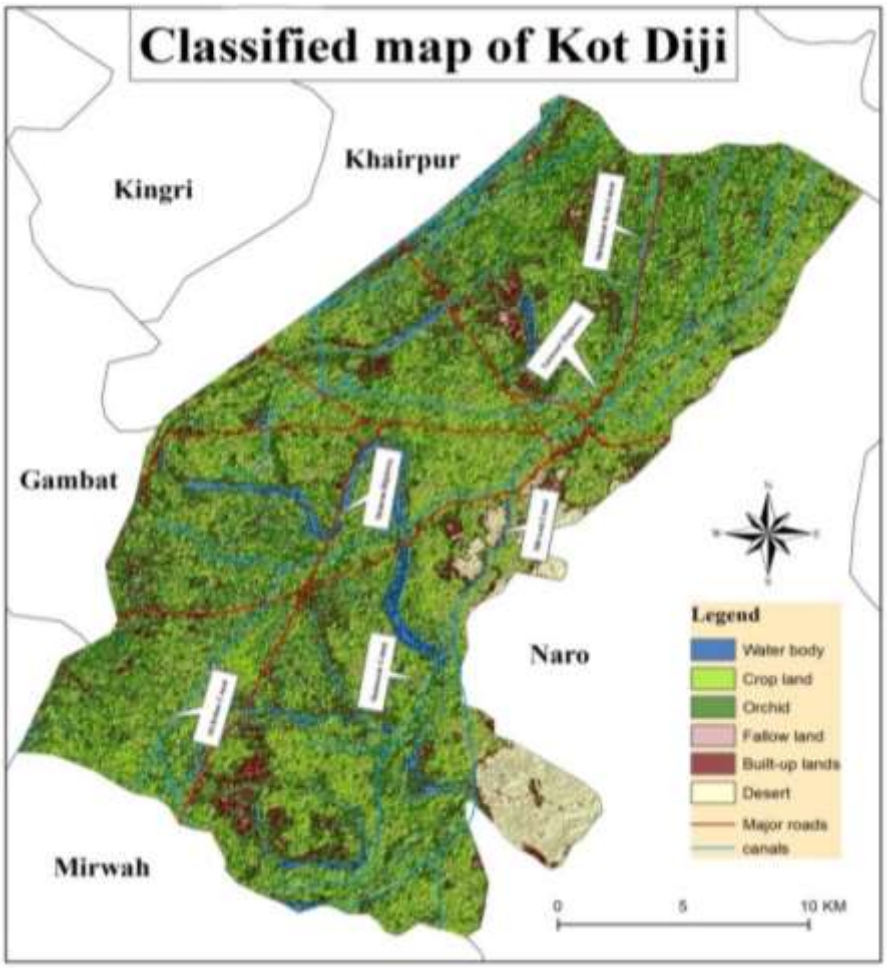

Fig. 2. Classified map.

Topography

The land of Kot Diji is mostly flat having low elevation. Most of the land is covered by agricultural lands due to fertile soil that supports crop cultivation. In Sindh province, there are total 14 canals and Nara canal is considered as one of the largest canals. Mir Wah canal is being used for irrigation and drinking purpose. Besides, Shah Nawaz canal that are originating out from Mir Wah canal, also support agriculture and inland fish farming of Kot Diji area.

Climate

Climate of Kot Diji is predominantly Arid. Summer season prevails for about eight months while winter season prevails for only four months. Summers are mostly hot with average weekly temperature up to 50°C especially in the month of June. However, the temperature varies during the monsoon season when rainfall takes place the most. Winter season is short but cold with average weekly temperature 5°C.

Land use of Kot Diji

The study area, Kot Diji is categorized into different types of land use i.e. crop land, water body, orchid, fallow lands, built-up land and desert. Crop lands share large area in Kot Diji because agriculture is considered as main source of livelihood of people there. Some major canals like, Ali Bahar canal, Shahnawaz canal, Mirwah canal and Mohabbat canal that support agriculture in study area as seen in (**Fig. 2)**. Besides, two major highways like National highway and Mehran highways were also highlighted as they describe the infrastructure of the city and provide easy access to market. Kot Diji shares its eastern boundary with Nara desert of Sindh.

Importance of Inland fish farming

In Pakistan, aquaculture is the only sector that can fulfill the food demand of increasing population after agriculture. By the passage of time, Agriculture is losing its crop productivity due to rising cases of waterlogging and salinity. One of the viable options to meet the rising demand of food in the country is to focus on aquaculture in Pakistan. Like other aquaculture activities, fish farming is considered as one of the most common practiced activities worldwide. About 75% of fisheries are fully exploited worldly (Bandira *et al.*, 2021). Fish farming is considered as world's rapid growing food production (Filipski and Belton, 2018). Lands having salinity issue with low crop yield can be changed in to fish farm (Aslam *et al*., 2020). Being rich in fish potential, Pakistan is having low production of fish as compared to other developing countries as it hardly shares 0.4% to country's GDP (Gop, 2020-21).

Methodology

Following methodological framework (Fig.3) was developed to achieve objectives of this study:

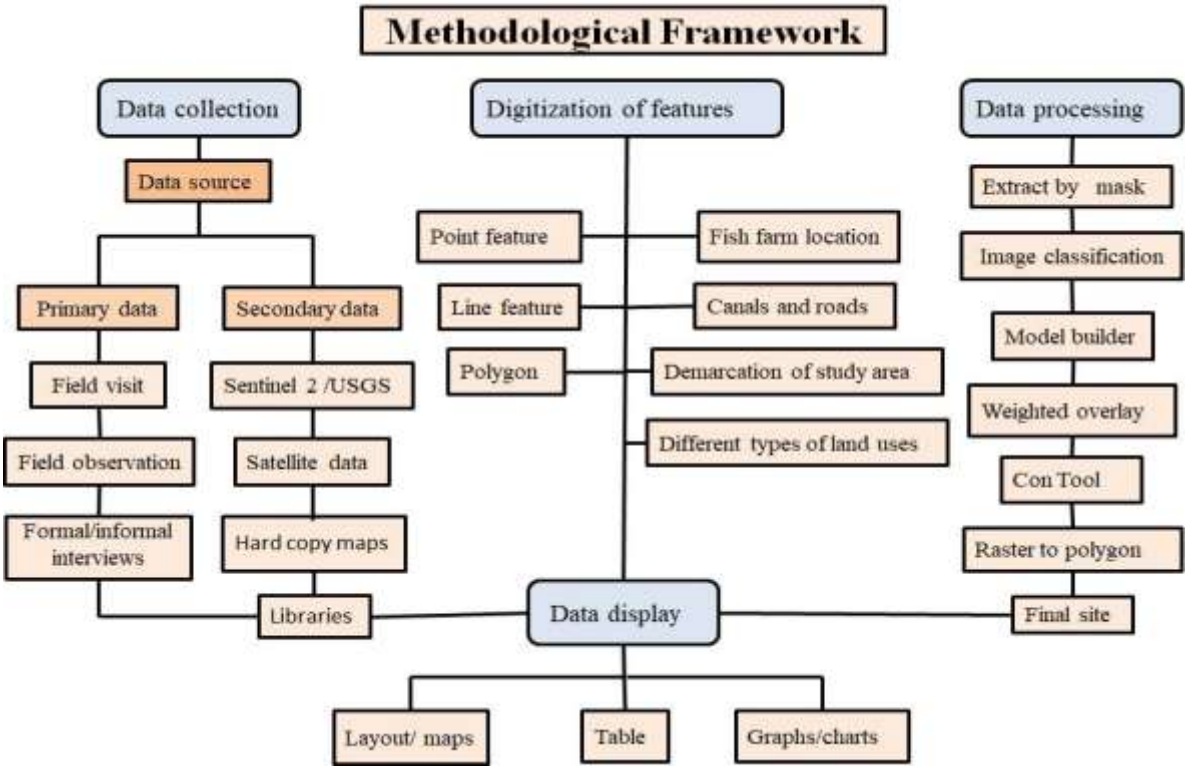

Fig. 3. Methodological chart.

Data collection

In this research, two types of data were collected, primary and secondary data. Field surveys were conducted to specific sites where people were engaged in fish farming. During survey, fish farms that already existed in study area were visited and their coordinates were also noted. A part from them, formal and informal interviews were conducted from the people who were engaged in fish farming activities and information regarding existing fish farms, farm size, breeding time and impact of seasonal variations etc. were collected. Data that has been published in different forms is known as secondary data. There are different sources of secondary data include libraries, records, biographies, newspapers, data archives, internet articles, published censuses or other statistical data, Research articles by other researchers (journals) and Databases, etc. Satellite imagery of study area of sentinel 2 and DEM (Digital Elevation Model) data were downloaded from official website of USGS (United States Geological Survey). Arc GIS and Google Earth software technology were used for further processing the data collected through primary and secondary sources.

Data Processing

Sentinel 2 image with 20m spatial resolution were used for land use classification. The downloaded image was extracted by extract by mask tool in Arc GIS version 10.8 software for further processing.

Image classification:

In this process, satellite image was divided into different groups based on the land uses visible on image. Unsupervised classification was done on extracted image of study area with Iso-cluster tool. Image was classified into 20 different spectral classes. These classes were converted into thematic classes by giving each feature a specific name and color. For instance, water body, crop land, fallow lands, and built-up lands were given different colors for better results.

Location of existing fish farms, canals and roads in Kot Diji

Locations of already existing fish farms were marked by applying the coordinates values collected during the field survey. These locations were validated with the help of satellite image of Google earth by cross-checking the values of longitude and latitude. Those selected marked points were added to Arc GIS software through KML to layer tool from arc toolbox. Besides, main roads and canals are also important features that were also highlighted as shown in **Fig. 4.**

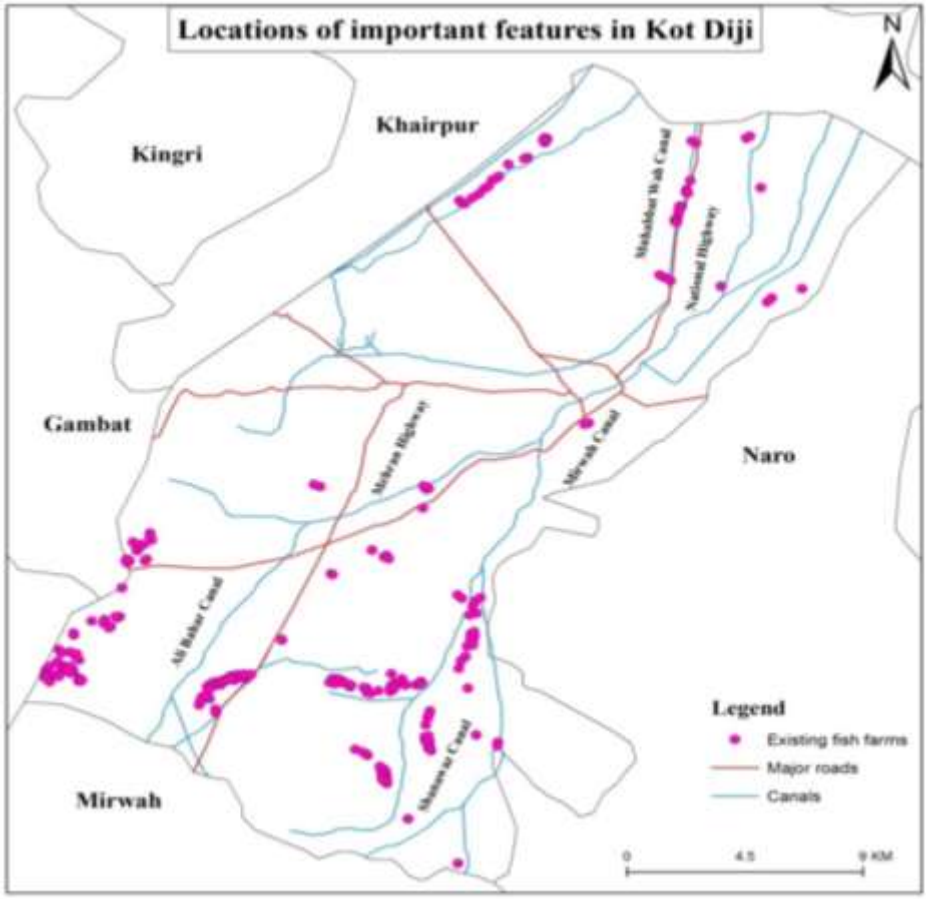

Fig. 4. Important features of study area.

Creating a Model

A Spatial Analysis model was created through ArcGIS software to find out new suitable sites for the construction of fish farms.

Slope

Study area was classified into steepness and gentleness of terrain after applying the slope tool. Result shows no variation in the elevation values because the study area is situated on lower Indus plain with gentle slope. This is a favorable condition for the construction of fish farms.

Euclidean distance

Euclidean distance gives distance of each cell to the closest source. Euclidean distance tool is used to find the nearest point from existing location of fish farms to create suitability maps.

Reclassification of data

Reclassify tool helps in reducing the higher number of classes into lesser number of classes and makes the data more precise and meaningful. Slope, land use and existing points of fish farms shared a different value that was difficult to combine these floating values. Most suitable site map will be identified while combining all of these cells with common measurement. Reclassification process was applied on already made 20 classes and reduced to 10 classes for further processing.

Weighted Overlay Analysis

After reclassified data, weighted overlay analysis tool used to find out the most appropriate site for the construction of fish farms. WOM (Weighted Overlay Method) was applied in creating susceptibility map that showed 80% accurate results (Lau and Zawawi, 2021). Before adding reclassified cells of study area, slope and distance to fish farms in to weighted overlay table, set the evaluation scale as 1 to 10 by 1. All the features were given different values according to their level of suitability because each factor has its own suitability for the construction of fish farms. For instance, built-up lands were given a restricted value (0) because they are not suitable for the construction of fish farms. Higher value 10 was given to the waterlogged and saline lands because they are considered as ideal place for the construction of fish farms. Similarly, different values were given to different land features like crop land, orchids and fallow lands based to their suitability.

Conditional (con) tool and majority tool

Con tool was applied after WOA in order to get sites for the fish farms. After applying con tool, multiple cells were highlighted as optimal locations with different sizes. Small cells are better be used for fish hatchery rather than fish farming. Therefore, majority tool was applied to subside the small cells. Fish farms that are being constructed on more than 25 acre land are considered as more beneficial and successful.

Model builder

Following are the complete weighted overlay model:

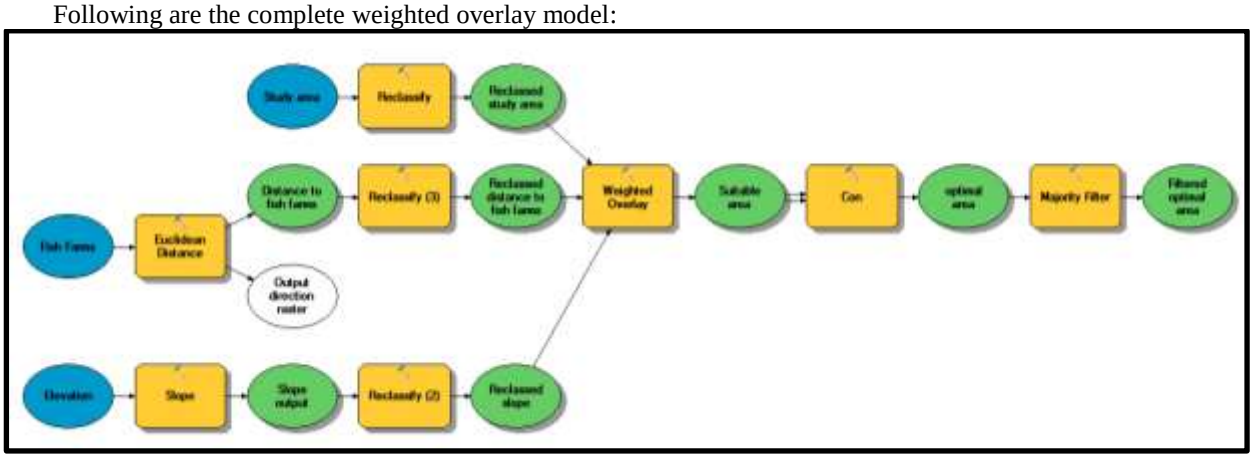

Fig. 5. Weighted Overlay Model.

RESULTS AND DISCUSSION

Reclassification of Kot Diji

Reclassified process merged built-up lands and desert in to one class because fish farms could not be constructed there. That class was named as built-up lands**.** The reclassified result showed five different classes, water body, orchid, crop lands, fallow lands and built-up lands as shown in **Fig. 5**.

Table 1. Area (km²) and percentage (%) of different land use.

S.No	Land use	Area (km²)	Percentage (%)
1	Built-up lands	43.26	7.91%
2	Orchid	205.79	37.64%
3	Fallow lands	55.27	10.11%
4	Crop lands	208.96	38.22%
5	Water body	33.37	6.10%

As seen in **Table 1** the largest land use is covered by crop land as it shares 38.22% area. It is because more than half of the population of Kot Diji area is engaged in agriculture sector. Land use named water body only shares 6.10% area because this is a dry area with insufficient rainfall and limited water resources. Land use like orchid, fallow lands and built-up lands share 37.64%, 10.11% and 7.91% area, respectively.

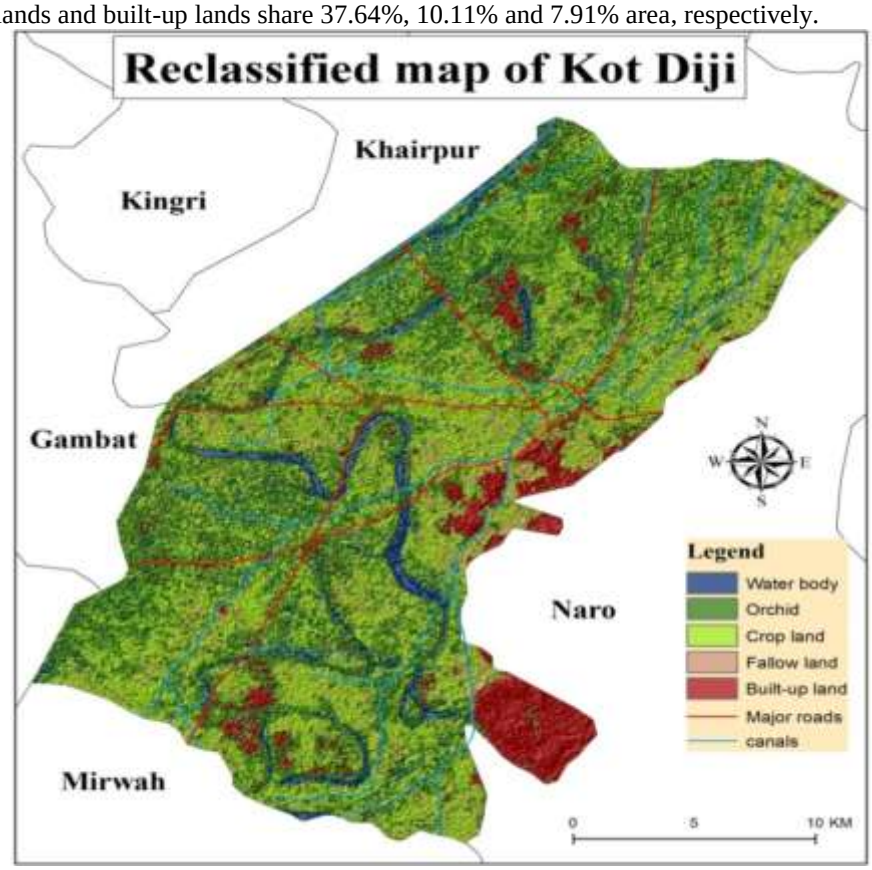

Fig. 5. Reclassified map of Kot Diji.

Suitability Analysis

Suitability analysis was performed by applying weighted overlay analysis technique to find out the most suitable location for fish farm. After running weighted overlay tool, land was categorized in to five classes of suitability like most suitable, more suitable, suitable, less suitable and not suitable. Most suitable sites are shown on the west-central part of the Kot Diji taluka as water resources are available near them. Other segments of most suitability site appeared on the north- eastern side and southern end of the study area where water channels are also present. It can be seen that all of the suitable sites for the construction of fish farms appeared near the water channels. It is believed that accumulation of surplus water reduces the fertility of agricultural lands and makes them unsuitable for crop production. While suitability sites appeared near the water resources that is considered an important factor for fish farms. Most part of suitable class is shown in the center of the study area as they include fallow and crop lands having low capacity for crop production. Less suitable class is present on major part of the northern and southern part of study area as seen in **Fig. 6**. Not suitable name was given to the built-up areas because fish farms cannot be constructed there. Major roads of the Kot Diji were also mentioned because they are the main source of connection between farms and market.

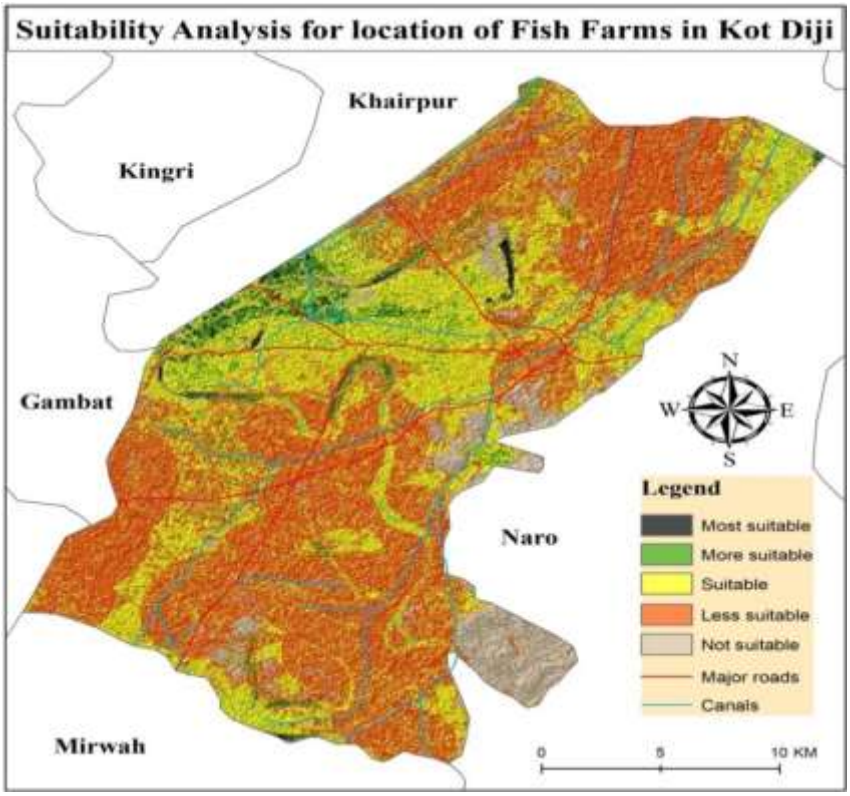

Fig. 6. Suitability analysis map.

Suitability Classes

Reclassified and weighted overlay techniques applied on raster layer to find out the suitability classes for the construction of fish farms. Following section described the land uses and their suitability for the construction of fish farms.

1: Most Suitable

The most suitable sites were given to the lands that are under waterlogging and salinity. These types of lands do not support the crop production and have very low crop potential. These types of lands are considered as ideal for the construction of fish farms. During survey most of the fish farms were seen that were developed on waterlogged and saline lands. Those farms are working successfully with good earning. Therefore, most suitability class was given to water body and it was weighted as 10.

2: More Suitable

The more suitable class was given to fallow lands after water body. Fallow lands are those lands that are being left for one or two years as vacant without any crop production to regain fertility for next cropping season. It means that the fertility ratio of fallow lands is already low as compared to other lands forms; therefore, they were ranked as 8.

3: Suitable

After fallow lands, cropland was given the suitable class and weighted as 5. Croplands are less suitable for the construction of fish farm. It has been seen that crop lands were changed in to fallow lands after excess of multiple crop cultivation that results losing fertility. When crop lands will become unable for any production then they can be better used for the construction of fish farms.

4: Less Suitable

Orchids were weighted as 2 and considered as less suitable for the construction of fish farms. Unlike crop lands and fallow lands, orchids exist for long period. Besides, orchid's lands hardly lose their fertility. Therefore, they were given name as less suitable for the construction of fish farms.

5: Non Suitable

The built-up lands are considered as non-suitable for the construction of fish farms. It is because a fish farm cannot be constructed on built-up land i.e. residential area or any commercial building. Therefore, the built-up lands were given non suitable class and weighted as restricted.

Following Table 2 shows the suitability analysis of land use for construction of Fish farms in Kot Diji.

Table 2. Suitability Analysis of land use of study area,

	Suitability class	Level of suitability	Ranked
1.	Water body	Most suitable	10
2.	Fallow lands	More suitable	8
3.	Crop lands	Suitable	5
4.	Orchid	Less suitable	2
5.	Built-up lands	Not suitable	0

Final site selection

In this research, it was expected that only lands having waterlogging and salinity problems would better be used for the construction of fish farms. According to (Chughtai and Mahmood, 2012) waterlogged and saline lands are considered as ideal places for the construction of fish farms. However, result came beyond the expectations because multiple sites were selected for fish farms along with fallow lands and crop lands. Among them author had to find out the best site for the construction of fish farms. After applying con tool and majority tools, most of the sites were filtered and sites having area more than 25 acres considered as a final location for the construction of fish farms. So, it is better to change the form of land from agriculture to fish farms. Following map showed the final sites in different colors **Fig. 7.**

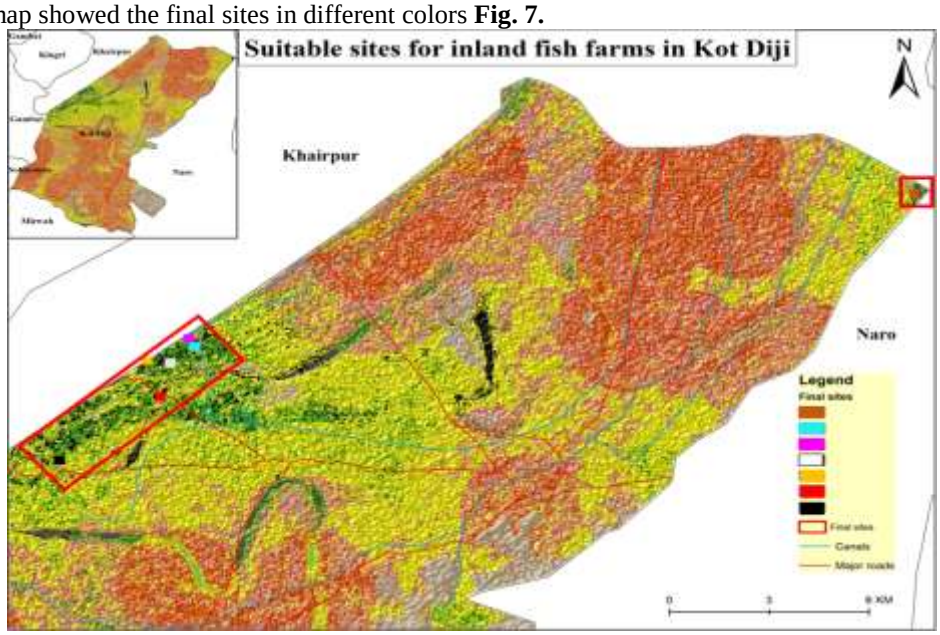

Fig. 7. Suitable sites for inland fish farms.

Below Table 3 shows polygon with their area (m²) and they are considered as final sites for the construction of fish farms (**Table 3).**

Table 3. Final sites for construction of fish farms.

	Shape	Color	Area (m²)
1	Polygon		1074.77
2	Polygon		1074.76
3	Polygon		1074.75
4	Polygon		273.87
5	Polygon		273.87
6	Polygon		273.86
7	Polygon		273.86

Conclusion and Recommendations

The study was conducted in Kot Diji taluka district Khairpur that focused on the lands that do not support crop production due to waterlogging and salinity problems. The main purpose of this study was to find out the most appropriate site for the construction of fish farms by using GIS based Spatial Anlaysis techniques. In Pakistan, agriculture sector does not meet the demand of food resources of the growing population, therefore, focusing on aquaculture will not only fulfill the food demand of people but also provides employment to them. GIS techniques were used that helped in identifying some suitable sites for construction of fish farms. The result showed that total seven (07) sites were being selected with different size of polygons. These sites are considered as most suitable sites for the developmet of fish farms. According to Gallego-Alarcón *et al.* (2019) and Robin (2021), rain-water is a good source of water for aquaculture and can be used for fish farms in future after taking some initial measures.

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