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RESOURCE MAPPING ON POTENTIAL AQUACULTURE DEVELOPMENT IN GOPALPUR UPAZILA: A GIS PERSPECTIVE

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ABSTRACT

A GIS based study was undertaken to map the available resources to evaluate their dependability in aquaculture development in Gopalpur Upazila under Tangail district. Accordingly, criteria were identified; data were located, collected, compiled and incorporated in to the computer for analysis followed by the approach by Kapestky (1994). The sub models were weighted according to their role in aquaculture development. Finally, Multi Criteria Evaluation (MCE) was employed to ascertain and priorities the most suitable areas for aquaculture development in the region. The study has identified 4 km^2 very suitable land parcel which is situated in the middle and eastern part of the area where all most all the criteria coincide well. Moreover, model has also identified 194 km^2 moderately suitable lands which covered all most all the Upazila. However, a small tip of land parcel (1%) falls under marginally suitable category located in the extreme periphery of the eastern region which may have not matched some of the criteria well. The outcome of this analysis was verified with the fish production data and most availability of fishes in the area which fairly matched with result.

Key words: Aquaculture, resource mapping, GIS, potentiality, development.

Introduction

In Bangladesh, fish and fisheries contributed approximately 63% of the total animal protein intake. Fisheries sector is contributing 2.43 % to the national GDP and 22.14 % to the agricultural GDP. About 19.5 million people are directly or indirectly involved in this sector. Labour employment in this sector has been increasing approximately by 3.5% annually (DoF, 2023). Per capita annual fish intake is 24.75 kg whereas the minimum requirement is about 18.0 kg for normal growth (HIES, BBS, 2022). Rapid growth of population, modification of water courses by damming, drainage and irrigation diversions and modification of the environment by deforestation and agriculture have resulted in an increasing pressure on fish stocks of inland water bodies and thus fish catches are decreasing. More food protein needs to be produced and a contribution can be made to this by increasing fish production through extension of aquaculture and inland fisheries. The scope for inland aquaculture is indicated by the projected decline in world capture fisheries over the next few decades (Meaden and Kapetsky, 1991). Aquaculture is playing a major role in employment generation, animal protein supply, foreign currency earnings and poverty alleviation in Bangladesh. Assessment of suitable sites is fundamental for planning of aquaculture expansion. Potential sites for various types of aquaculture developments can be done by applying appropriate criteria, both environmental and socio-economic. Earlier, site selection was aimed at ensuring economic profit and increasing production, but at present, environmental factors is used to ensure sustainable development. Appropriate socio-economic factors will ensure the profitability of the industry, while environmental factors will maximize production and prevent adverse impacts on the environment (Jarayabhand, 1997). For proper planning, management and sustainable development of aquaculture in a particular area, it is necessary to identify the specific problems of that area. To identify the problem of sustainable aquaculture we can use Geographical Information Systems (GIS) as a tool. By using of GIS as a tool, we can select the suitable place for aqua farm establishment. This study is built mainly on two GIS studies: (i) The analysis of factors important for aquaculture development and operation (Kapetsky, 1994) and (ii) the development of farming system models in Latin America (Kapetsky and Nath, 1997). In spite of having enough aquaculture resources in the study area, there is shortage of fish production than their demand. The area will be able to produce more fish than the requirement through proper planning, and management, application of agricultural by product and wastes from livestock. By using GIS, we can develop a database for the planning of aquaculture and identify a suitable site, which can fill up the domestic demand of fish, create employment opportunity, help to alleviate poverty, increase the source of income of the people in the region.

Materials and Methods

The purpose of the present study was to identify the efficient, cost effective and suitable areas for potential aquaculture development in Gopalpur Upazilla of Tangail District through GIS based modelling. To identify the potential sites for fish culture, a number of criteria were selected followed by the approach of Kepetsky (1994). This study has resulted a suitability map and a database for fish culture potential in the study area using GIS as a decision making tool considering the factors: infrastructure, soil, support, agricultural inputs, water sources and market facilities. In order to evaluate the fish culture potential in the area, the data were collected from government and non-government office of the Upazilla and field survey was done where necessary. Data were also searched from books, CDs, Banglapedia and similar research papers. Then the related data were compiled and prepared for computer analysis. As it was a computer based decision making venture, all the collected data were incorporated into the computer by the keyboard, digitizer, scanners, CD-ROMs, computer-compatible taps, pen drives, or via networking from external sources. The collected maps were scanned in blocks as JPEG format and then were converted into BMP. The blocks were then joined in Paint-shop Pro5.0, which then imported into IDRISI to incorporate into the GIS databases using import facility and attribute data from the keyboard. Digitized data were edited using DIGI-EDIT for Windows-Version 1.05 software. Some of the tabular data were processed in Microsoft Excel before being imported into IDRISI. Conversion of vector file into image file was done. After applying distance and interpolation technique the vector file was then reclassified. The reclassified images were then weighted and different sub-models were obtained by MCE. Constraint file was obtained by overlaying different settlements, roads, rivers, khals, beels. After that weighting and final MCE was done to get final result.

Results and Discussion

This chapter represents the outcome of GIS analysis of resource mapping and their role in potential aquaculture development in Gopalpur Upazilla of Tangail District. The results for each criterion are presented as reclassified images at first, and then sub-models were formed using these images. The sub-models are then used in the final analysis. The amounts of reclassified potential areas in each sub-model are summarized in Table 1 and the corresponding spatial distributions of the areas are shown in Figs. 1-24.

The final outcome has been derived from the integration of different sub-models like soil quality, water sources, extension support services, agricultural inputs, infrastructure and markets using MCE module. Four levels of suitability have been obtained from the GIS analysis for fish farming potential. It is clear that Gopalpur Upazilla is moderately favorable for fish farming. Only 2% of the area is under very suitable category. However, all most all of the study areas (97%) are under moderately suitable category. The area of marginally suitable category of land is negligible in the Upazilla and currently not suitable category is totally absent. Availability of inputs are not sufficient in the Upazilla which hindered the suitability. However, the shortage of its agricultural byproduct can be supplied from outside of the Upazilla and potential aquaculture development can be possible in the Upazilla. A considerable number of criteria had been used in site selecting process for potential aquaculture development in the study area. Decisions may be characterized as single or multi-objective use in nature, and can be used on either single or multiple criteria (Aguilar, 1996; Carver, 1991).

Table 1. Suitable areas (%) represented by different sub-models for aquaculture development in Gopalpur Upazilla

Name of sub-model	Very Suitable (sq. km (%))	Moderately Suitable (sq. km (%))	Marginally Suitable (sq. km (%))	Currently not Suitable (sq. km (%))
Water	2 (1)	45 (21)	159 (75)	6 (3)
Soil	47 (22)	141 (67)	23 (11)	0
Input	0	0	154 (73)	57 (27)
Infrastructure	198 (94)	11 (5)	2 (1)	0
Support	184 (87)	27 (13)	0	0
Market	37 (18)	150 (71)	23 (11)	0
Final result	4 (2)	194 (97)	2 (1)	0

Most of the data were in maps and tabular formats. Maps of the Local Government Engineering Department (LGED) was the base map for this study. On the other hand, soil map produced by Soil Research Development Institute (SRDI) was crude and RMS error was high which affected the resampling result. The problem was overcome through choosing enough corresponding points in both the maps. Some data were also collected from literatures. Most of the data were secondary and either digitized or scanned for incorporation into the GIS databases. Some of the first hand data were also incorporated through interpolation techniques.

The criteria considered for the study were analyzed through MCE because of its simplicity, its treatment of multiple objectives, and its capacity to handle different types of criteria. It can analyze complex trade-off between choice alternatives using the different environmental and socio-economic impacts (Carver, 1991). MCE is especially useful in reflecting the performances of decision-makers to test validity of the weights used and ranking of the alternatives (Jankswski and Richard, 1994). MCE was explicitly designed to satisfy the fairness of criterion and this process was found to be very efficient in establishing weights of factors. Good results were obtained using the methods when a small number of factors were used. However, Ross (1998) and Aguilar (1996) consider that if the number of layers exceeds about 10, it is difficult to obtain good results through MCE, even in the hands of an experienced modeler. In IDRISI for windows 2, MCE module cannot handle more than five factors together. But the upgraded version of it i.e. IDRISI-32 can handle more than five factors and this study involved six criteria and analyzed in IDRISI 32 environment.

One of the important tasks was to give weights to the criteria in the site suitability analysis through the MCE decision making process. It is apparent that different results can be achieved from the same set of data at the weighing stages since different individuals can consider different factors to be more or less important for their own objectives (Salam, 2000).

In the present study, GIS predicted that there is only 4 sq. km (2%) of lands are very suitable for potential aquaculture development at Gopalpur Upazilla due to low production of rice, wheat and animal wastes. On the other hand, mustard oil seed is an important component that used as fish feed is about to not grown in the study area except Alamnagar and Mirjapur union. Water availability is also a crucial factor for getting very less amount of suitable area. Most of the areas of the upazilla i.e. 194 sq. km out of 200 sq. km are under moderately suitable category because almost all the facilities satisfied those areas except inputs and water availability. In this case, the moderately suitable area can be converted into very suitable by incorporating inputs from outside of the upazilla. There is only 2 sq. km (1%) of areas are marginally suitable. In this case, most of the facilities are more or less available in the areas and may be converted into satisfactory for fish culture if lower available facilities can improve. It is important that currently unsuitable category is totally absent in this area for potential aquaculture development due to all the facilities are more or less satisfactory.

Animal wastes play an important role in agricultural inputs sub-model and are widely used in small-scale and commercial fish farming systems. The objective of animal (livestock) wastes estimation is to predict the amount of manure, which could be available for fishpond fertilization in the region. Due to lack of manure data, livestock density was used as a surrogate measure of manure availability. The number of cattle, buffalo, sheep, goats, and poultry were collected from Upazilla livestock office. The total amount of manure produced daily by various animals depends mainly on their live weight (LW). Sheep, for example, produce daily one tenth of their live weight in total wet wastes, consisting of solid wastes and urine (Coche *et al*., 1998). However, oxygen demand increases when organic matter is applied to the ponds, for this reason the amount of organic matter to be used at one time should be limited. This safe amount is usually expressed in kilograms of dry matter (dm) per hectare per day, abbreviated as [kg. dm / ha. /d]. FAO estimates (Coche *et al*., 1998) the production of farm animal wastes daily were used in this study (Table 2). The authors provided a range of weights, which correspond to typical livestock from which manure is obtained. These values are approximate estimates for this study, and they may change in time and with animal species, age and feed ration, type of confinement and method of manure handling.

Table 2. Livestock weight estimate and manure production per kilogram bio-mass per day (adapted from Coche *et al.*, 1998; Little and Muir, 1987)

Animal Type	Mean individual live weight (LW) [kg]	Total weight of waste* per day		Solid wastes per day	Total fresh wastes* (Solids only)
		% LW	[kg]	[%]	[kg/1000kg LW/day]
Cattle	210	6.2	13	69	60
Goat/ Sheep	30	7	2.1	47	70
Poultry	2	4.8	0.048	0.02112	21

* Solid waste and urine

The production of agricultural by-products in the region is not satisfactory. The good agricultural production generally favour aquaculture and vice versa and good agricultural land can be used as a indicator of areas where aquaculture might flourish (Little and Muir, 1987). In Bangladesh, agriculture is the single most important economic activity and is a good indicator of potential aquaculture development in the region. Kapetsky and Nath (1997) noted that the presence of good agricultural land is an important indicator of aquaculture potential in two ways:

- The development of agricultural land implies that at least a minimum amount of infrastructure has already been developed, such as roads, local labour forces, villages or towns for essential supplies.
- Agricultural by-products (rice bran, wheat bran and mustard oilcake) can be a source of fish feed or fertilizer.

However, it was difficult to predict how much wastes and by-product would be available for aquaculture, as there are many other competing uses for the same resources in the region. For example, animal wastes are extensively used as an agricultural fertilizer and for household fuel purposes. Rice husk, wheat bran and oil seeds are also used as a cheap source of animal and poultry feed in the region. Therefore, it is uncertain whether enough animal wastes and agricultural by products would be left for fish feed supplement or not (Bain, 2004). During the analysis of infrastructure sub-model it was found that all-weather motorable roads like pucca, katcha roads were excellent and covered more or less all over the study area. In my study area there is a hatchery. So, farmers can easily get fish fry from that hatchery. In the present study, a GIS database was created to locate potential sites for fish farming based on soil characteristics, water availability, support facilities, infrastructure facilities, inputs and market potential. A similar type of study carried out by Kapetsky *et al*. (1988) in Louisiana State, USA but they only considered soil characteristics and susceptibility to flooding. On the other hand, Salam and Ross (1999) in a study in the south-western Bangladesh developed series of models to identify and priorities the most suitable areas for freshwater prawn and brackish water shrimp farming and fish culture using 36 primary layers.

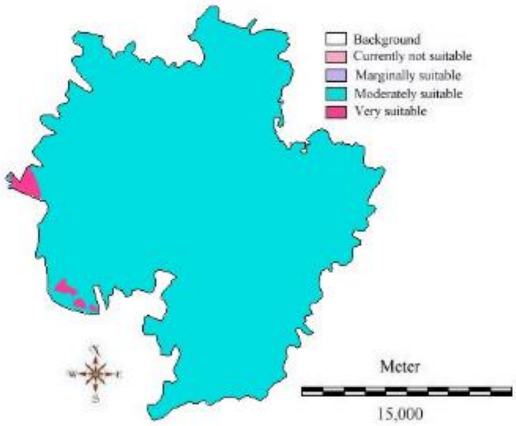

Fig. 1 Soil pH suitablity

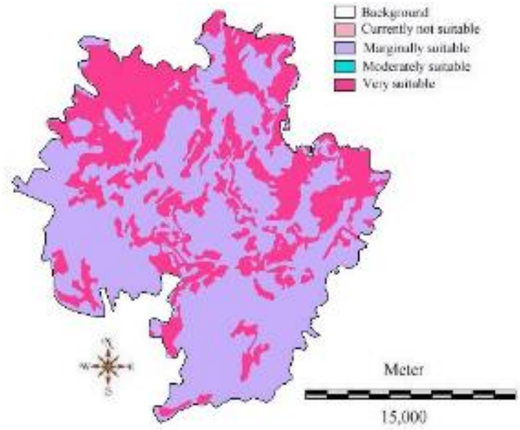

Fig. 2. Inundation

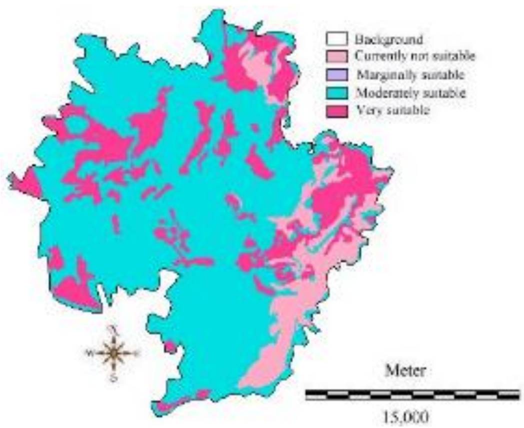

Fig. 3. Soil texture suitablity

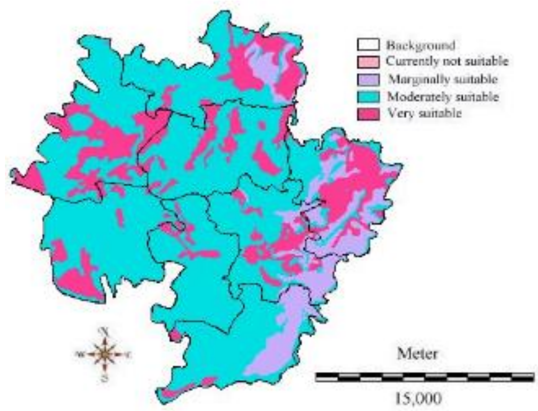

Fig. 4. Soil quality sub-model for fish farming

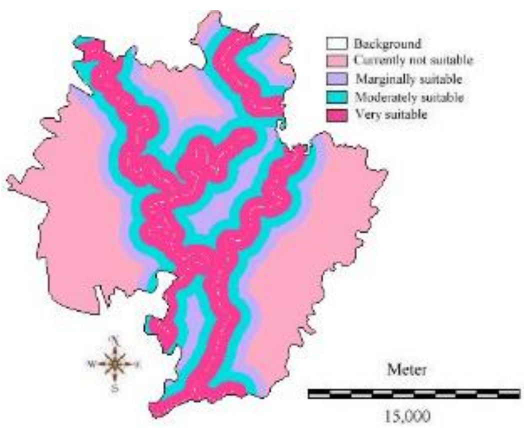

Fig. 5. Proximity to river

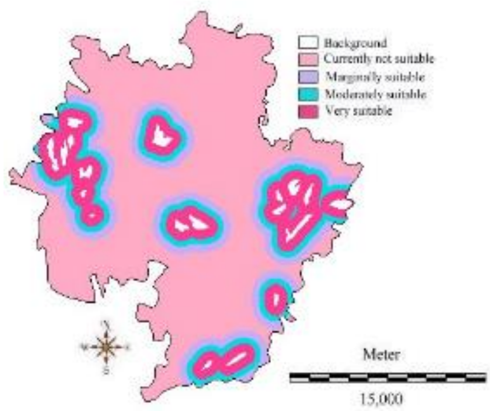

Fig. 6. Proximity to beels

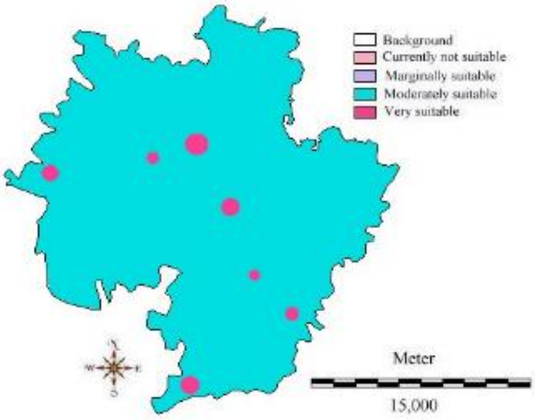

Fig. 7. Ground water level

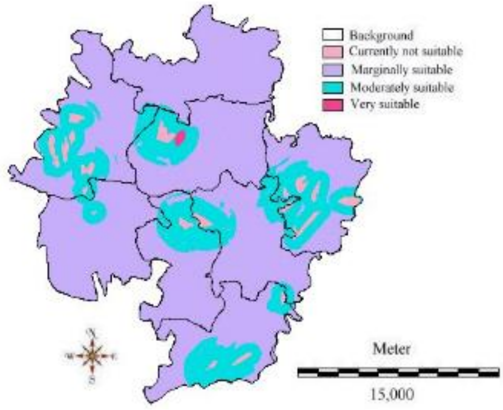

Fig. 8. Water sources sub model for fish farming

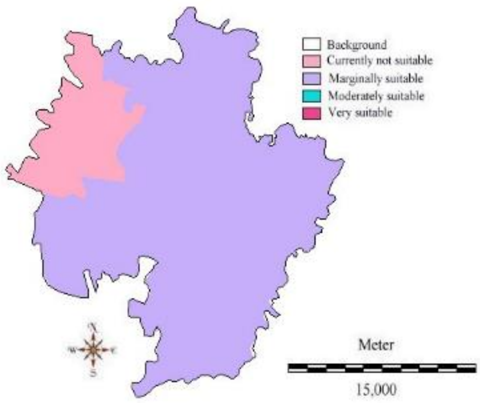

Fig. 9. Rice production input sub-model

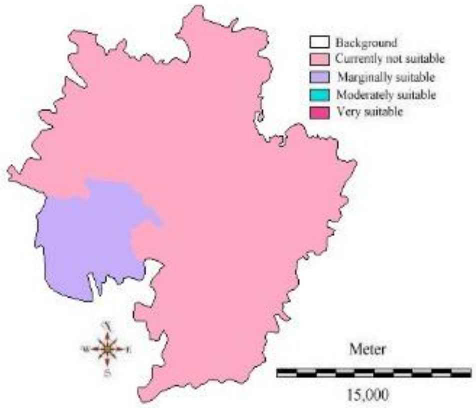

Fig. 10. Wheat production input sub-model

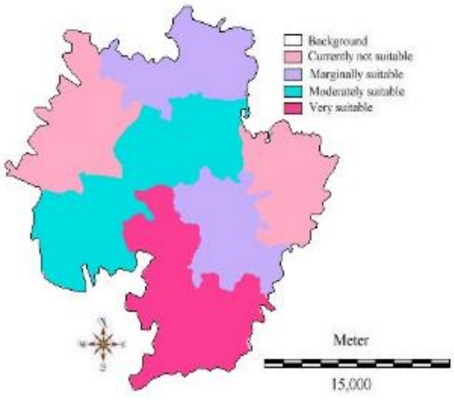

Fig. 11. Corn production input sub-model.

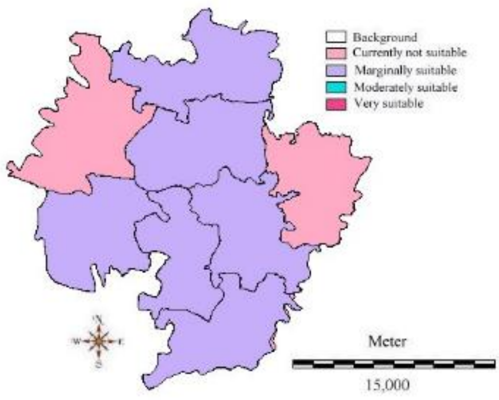

Fig. 12. Input sub-model for fish farming

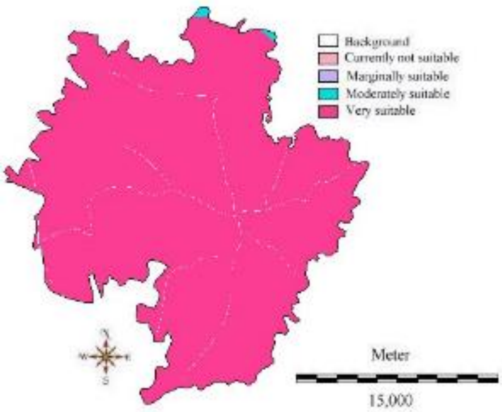

Fig. 13. Pucca roads sub-model

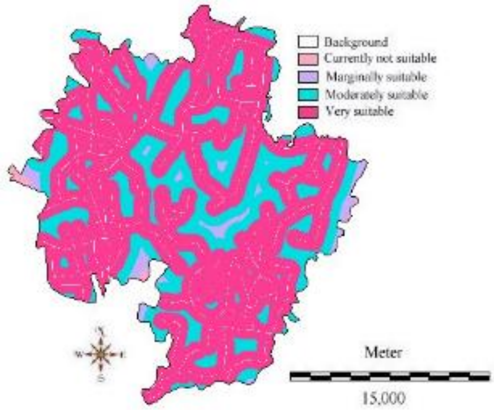

Fig. 14. Katcha road sub-model

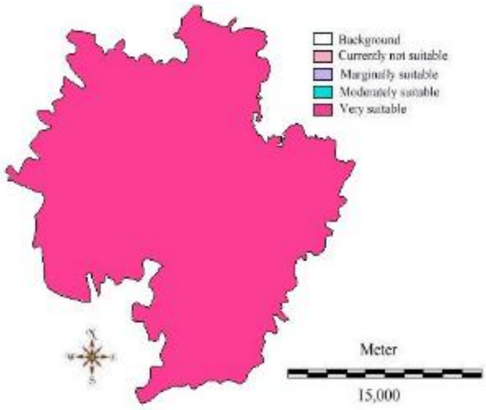

Fig. 15. Hatchery location sub-model

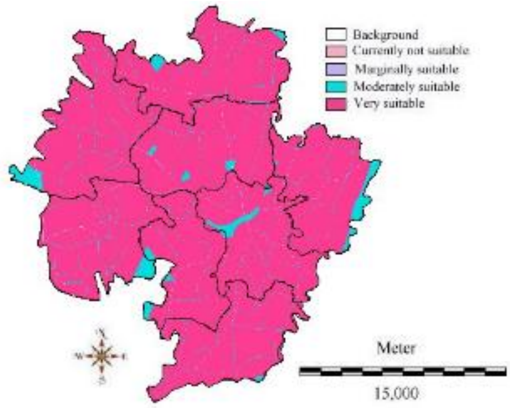

Fig. 16 Infrastructure sub-model for fish farming

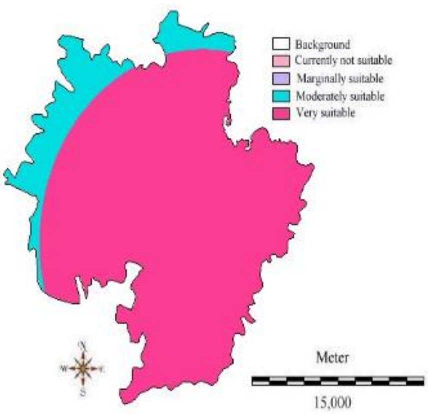

Fig. 17. Support ranges of UFO

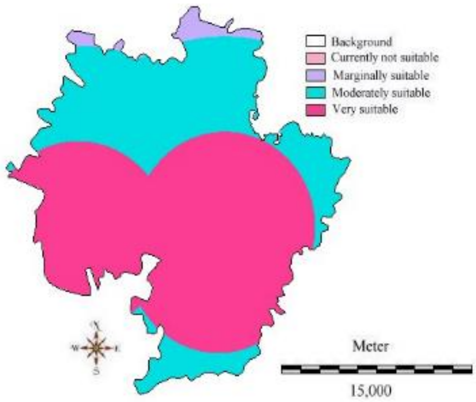

Fig. 18. Support ranges of NGOs

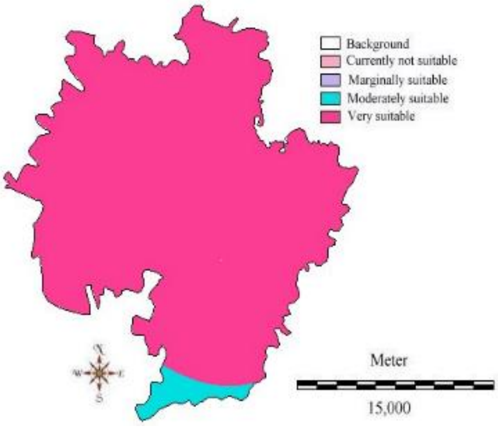

Fig. 19. Support ranges of Bank

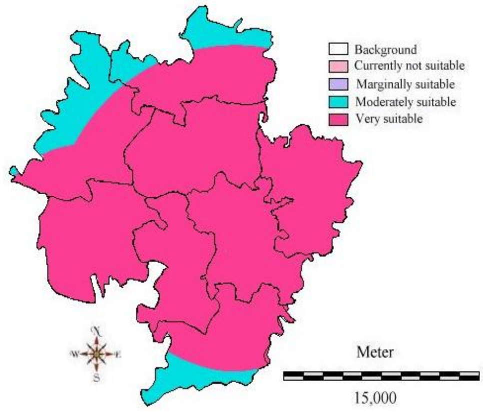

Fig. 20. Support sub-model for fish farming

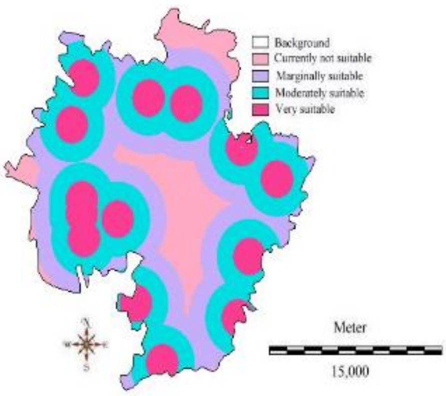

Fig. 21. Local market ranges

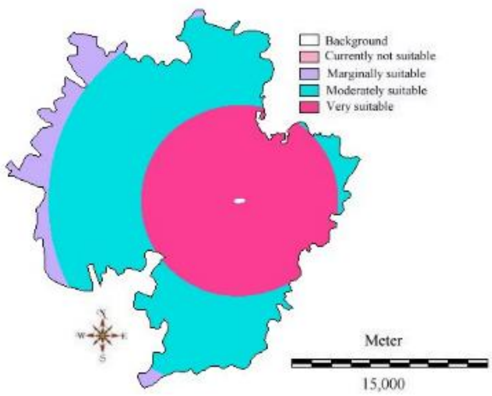

Fig. 22. Town market ranges

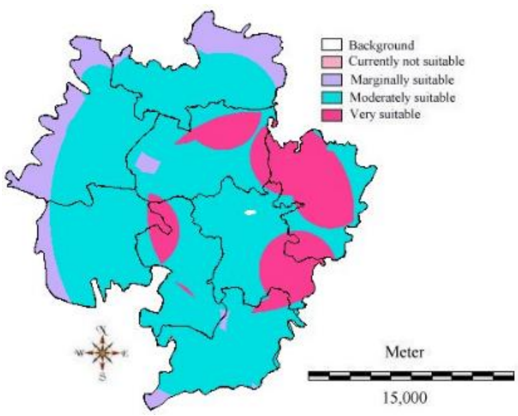

Fig.23. Market sub-model for fish farming

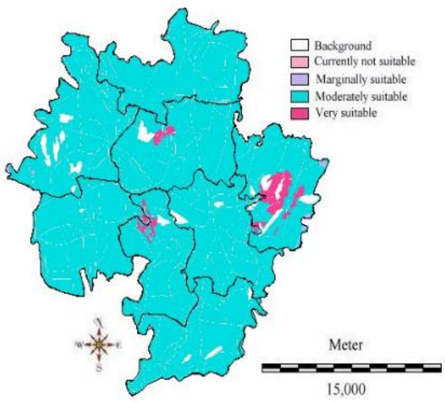

Fig 24. Final Result of the study

Several factors affected the outcomes of this study. The factors may have been derived from inaccurate data sources, availability of secondary or tertiary data, calculated data source from the Upazilla, their spatial and temporal variability and the analytic approaches and assumptions adopted here. Most of the possible problems affecting this study can be minimized or eliminated as more data become available and experience gained with aquaculture related GIS application. The benefits of using GIS for natural resource modelling, management and decision-making are clear. The wide range of application of the approach has recently been developed into aquaculture and fishery management and this trend is sure to continue. The strengths of GIS include the ability to handle a wide range of data sources and resolutions, speeding up the work and allowing for easy updating of spatial databases and the ability to handle time series analysis and to generate spatial output.

The essential utility of GIS lies in its ability to manipulate and overlay data in various ways and perform many analytical functions so that it can contribute to a faster and more efficient decision-making process in fisheries (Subhendu, 2013). The FAO recently launched a web portal, GIS Fish, to leverage global experience in Geographic Information Systems (GIS), remote sensing and mapping as applied to aquaculture and inland fisheries. For the purpose of resource availability analysis, although there are numerous technologies under development, GIS is still the most beneficial. GIS helps access food fisheries potential, assess the ecological health of river and lake basins, and allocate resources between fisheries management and aquaculture development. It also helps us identify the source, location and extent of negative environmental impacts. GIS allows us to devise practical plans for monitoring, managing and limiting environmental damage (Nath *et al*., 2020). The extensive model-building capabilities and the range of decision support tools allow real decisions to be made and trade-off allocations of land and resource use and their benefit to be evaluated quantitatively. In addition, to clarify the management benefits, the understanding of the processes and events, which such approach can elucidate, is very powerful and means that GIS has a role in research as well as in end-user applications (Ross, 1998).

Overall, it is noticeable that the GIS procedures have a strong effect on the outcome of the final results. It was found that the choice of weights could be applied even the Consistency Ratio (CR) is very low. Because the assignments are extremely flexible, the GIS models can generate a great variety of scenarios. To determine these weights, guidance was obtained from literature relevant to the study, and from the opinion of experienced personnel and staff. Ultimately, however, subjective decisions had been made. The outcome of the results was strongly dependent on the quality of the raw data (thematic maps or primary data).

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