Use of Information Technology in Aquaculture

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Introduction

Advances in Information Technology has profound impact on many fields including aquaculture. With the focus more directed towards development of aquaculture facilities, the application of modelling and other forms of electronic virtualisation is finding profound application in management of centres and expansion of facilities. IT areas like instrumentation and process control, data management, computerized models, decision support systems, artificial intelligence and expert systems, image processing and pattern recognition, geographical information systems, and information centres and networks are being very closely involved in the shaping up of efficient aquaculture projects and their upscaling in many countries around the world. In this session let us discuss the developments happening on these facets of IT vis-a-vis aquaculture and a detailed case study on the application of GIS based modelling tools in site selection issues in open sea cage culture.

Process control and Artificial Intelligence

Instrumentation, designing and process control of aquaculture systems have their base on the engineering inventions and innovations that happen around the world. These range from the fabrication of tanks, control systems etc. to parameter monitoring tools like those which measure temperature, conductivity, pH etc. Such instruments usually require a canopy monitoring setup, whereby critical values under various dimensions can be always kept tabbed. Needless to say these are possible by the computer based applications which provide the umbrella console. Archived data and their systematic analytics are part of any dynamic system which has self learnt course correction enshrined in it. Successful aquaculture ventures generate a parallel database of various input and out parameters which help charting a successful future course. Artificial intelligence and Decision support/ Expert systems are the tertiary processed information based on the foundation, functioning and forecast of the aquaculture systems. Such processed data and their logical outputs stand in good stead while building scenarios of extremities and planning medium and long term prospects for the aquaculture ventures.

Microlevel applications of Computer Vision tools

Continuing further from what was described in the previous paragraph, specifics of micro-application of AI/ML and its grand visualization as Computer Vision can be broadly categorized into the following.

Starting with the most common of applications like feed management to growth monitoring and then to water management, aeration, and temperature optimization the nuggets of what is observed through "computer eye" takes wings as palpable interventions through the wealth of AI/ML. These have moved from a somewhat rigid decision support systems to more dynamic human-less management like automated water filteration etc. Added to these is the sensor based myriads of signals and other pulses that assiduously builds up a streaming bigdata, that is both the fruit and root that take the process further. The latest of this string of synergistic developments on the fields of aquaculture and computer vision technology is the galloping performance of predictive analytics. Predictive analytics paves the way for aquaculture practitioners to not only strategize their upcoming actions but also work along the lines of the forecasted notions so that they can do the best for their livestock. Thus despite being an unconventional area of application, aquaculture has of late been reaping benefits of working on the para shoots of the developments like bigdata analytics, which initially inadvertently and later on on purpose makes each aquaculture entrepreneur understand the impact of inputs better and adjust the bar of caution as per the unforlding developments yielding in contingent plans. Thus, to say the least the present day ICT options enable aquaculture entrepreneur to have near full control of hitherto unknow factors, without precisely and independently understanding them, yet coming out with the best possible measure in face of their interactions. (Vásquez-Quispesivana, Wilfredo *et al*, 2022);

Geographic Information Systems (GIS) and Image Processing (IP)

GIS plays a major role in the development of georeferenced database of various parameters whose thresholds are critical for the study, planning and management of an area for Aquaculture. The digital information stored in the georeferenced format is quickly amenable to spatial and geostatistical querying, interpolation and stratification which is a very basic input for establishing aquaculture ventures. Marine GIS plays a very special role by way of including the depth as the third dimension and thereby giving options for interpolating ambiences in a three dimensional space. Such techniques when superimposed with the pattern recognition algorithms of IP can be a successful synergistic recipe for fast and efficient identification of favorable spots for aquaculture in a very large scale. IP as applied on satellite based imagery and the recognition of sub patterns in them coupled with the data supplied by the GIS for said spatial extents would go a long way in comprehensively scrutinizing vast expanses of target area. In the subsequent part let us discuss on more specific analytic solutions which are IT based in the field of aquaculture.

Application of linear programming in aquaculture

Linear programming (LP) is an econometric tool to get optimum solutions for modelled processes under certain constraints. With many common daily-use application-wares like electronic spreadsheets and statistical software like SPSS, SAS, R etc. having options to perform LP analyses, ease of its application in various entrepreneurial fields become all the more prevalent. There could be certain aquaculture projects, for example molluscan aquaculture, wherein the candidate species would be hung in ropes in its niche.

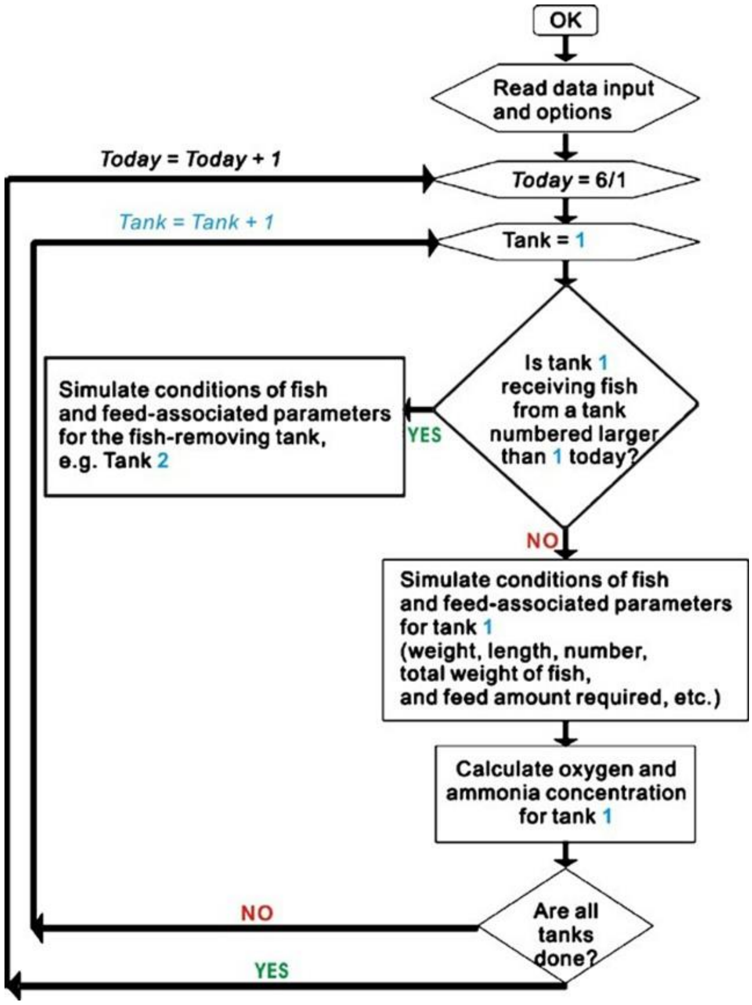
The growth and mortality rates at each stage of the animal are dependent upon the period of deployment and the duration until harvest. For a large scale operation LP based solutions can be obtained which maximizes the net present values of the profits for each stage of initiation. Input like market requirement and saturation point can be brought in as additional constraints to smoothen the system output. Production can be streamlined to stand robust against the inter seasonal activity fluctuations. Smoothening of the process like mollusc production to suite to the spiky market demand would give an efficient lever to control the most important manpower in such exercises, viz. manpower. Thus the dream figure of arriving at the throughput for a given area and spacing can be obtained.

Simulation modelling in flowing water aquaculture

Growing carps in flowing water (raceways) is comparable with a cyclic chemical process. With fish, feed and oxygen levels as the reagents and the larger biomass and waste as products, this system can be visualised. The efficiency benchmarks for the system are feed conversion and survival. Parameters like temperature influence the rate of reaction and growth potential. Economics of this system are based on the cost of inputs, the cost of recovering and marketing products and the quantity and value of the products created. The most pertinent managerial research for this kind of a setup is to manage the genetics, nutrition, disease prevention and water quality etc. in order to maximise the yield. Such efforts have resulted in development of simulation systems like RDSS (Wang *et al*, 2008). Towards finalising the simulation model, the following input parameters and their relationships established in various research publications could be used.

Parameter	**Link summary**
Design of raceway	Waterflow rate, exchange rate, length etc.
Condition factors for fish	length (age) weight relationships
Feed conversion	nutrition fact based linking of protein, carbohydrate and fat based calorific values and calories required per kg weight gain
Feeding rate	Length (age) based feed requirement of fish at different stages
Oxygen solubility in water	Saturated oxygen content in water at sea level as a function of temperature and appropriate pressure corrections
Concentration of dissolved solids	Reduction in dissolved oxygen due to salinity as a function of temperature
Oxygen consumption rate of fish	Oxygen consumption at a given day as a function of feeding rate of the day
Gravity aeration	Increased amount of oxygen in water falling through a specific distance
Production of ammonia	Metabolic rate computed as a function of protein fed

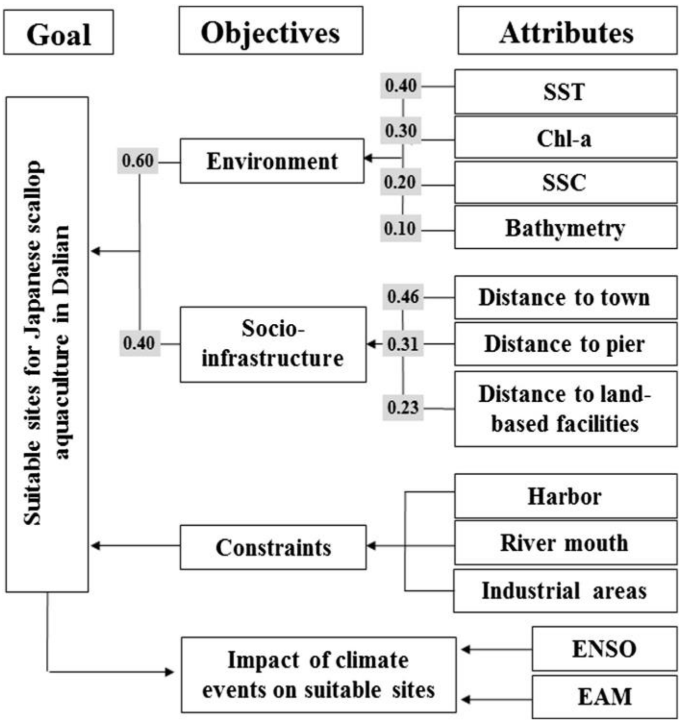
Using four groups of the input data viz. water data, raceway data, feed data and fish stock/ harvest schedule and the links listed in the above table the biomass dynamics of the fish being cultured can be simulated and related quality of production and the marketing margins can be worked our. The software for such simulations can be exposition with lucidity in the following flowchart adapted from Yin-Han Wang metal (2008).



Satellite based site selection methods

The site selection for aquaculture projects have many issues to me mulled including non-technical ones. A medium to large scale project must take into account all the climatic, oceanographic and biological parameters of the proposed site for obvious reasons. Added on to these would be some crucial socioeconomic and support factors too. It could be that many of them would be possibly extracted from remote sensing based imageries too. Micro data collection cannot be all pervasive and seasonally robust. Hence collation of information collected from satellite imageries always strengthen the modelling, scenario building and thus the planning exercise for such aquaculture ventures. Imageries backed with Marine GIS tools and statistical analyses can make these tasks easy and the results comprehensive.

A typical model which combines the above factors could be synthesised by many sub models. One such case is discussed in Yang Liu *et al* (2014) wherein satellite based inputs for marking harbours, townships, industrial area and river mouth extracted from land observation satellites were added to the classic environmental parameters while finalising scallop aquaculture projects. The schematic framework is given in the following figure. In this particular case thee sub-models involving environment, social infrastructure and constraints emerging out of harbours and area of nearby ton etc. The approach was to rank the parameters under each sub group on a scale from 1 (most ill suited) to 8 (most suited). A pairwise comparison based parameter weights were computed and the submodes branches were constructed. ModelBuilder module of ArcGIS was utilised to obtain the Weighted Linear Combination (WLC) using Multi Criterion Evaluation (MCE). The suitability scores for various regions were worked out in the above mentioned 1-8 scale. The climate events were indexed using monsoon index of the relevant spatial gradient and the Oceanic Nino Index (ONI) using Sea Surface Temperature (SST) anomalies. These two indices were integrated into the simulation model using stepwise multiple regression analysis to determine the underlying causes of climate impact. Correlations among climate indices, environmental factors and suitability scores for all seasonal changes were considered. Finally based on the spatial and seasonal suitability profiles of locations monthly suitable maps were generated for the study period and the crucial seasons and their “threshold” indices were noted down for consideration while planning the aquaculture initiative. Hence such combination of GIS based modelling coupled with inputs from satellite remote sensing data would efficiently help in developing such ventures. These models also have the possibility of being receptive to addition of more informed micro measured inputs like salinity, dissolved oxygen and fresh water discharge etc.



Site selection based on oceanographic parameters- an Indian case study with respect to open sea cage culture

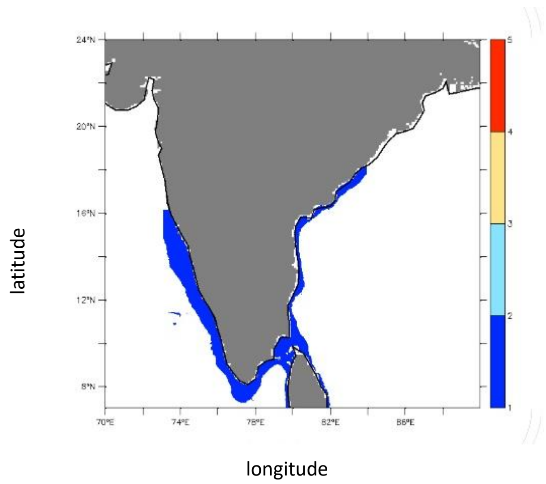
Open sea cage culture is becoming a promising area of aquaculture all over the world. It has been intensified and has created essential employment opportunities over the last two-decades in many countries. The location and amount of culture activity must balance the needs of conservation and economic return in a sustainable manner. Determination of site suitability involves careful consideration of social, economic, and environment factors. Environmental suitability forms the basis for planning exercises and management interventions With the development of the GIS and availability of remote sensing data, it is now possible to select environmentally suitable areas rapidly and systematically.

As described in brief previously, GIS has been widely used in mariculture development, including site suitability determination, zoning, environmental impacts, planning, inventory and monitoring of aquaculture and the environment, and competitive exploitation of common areas.

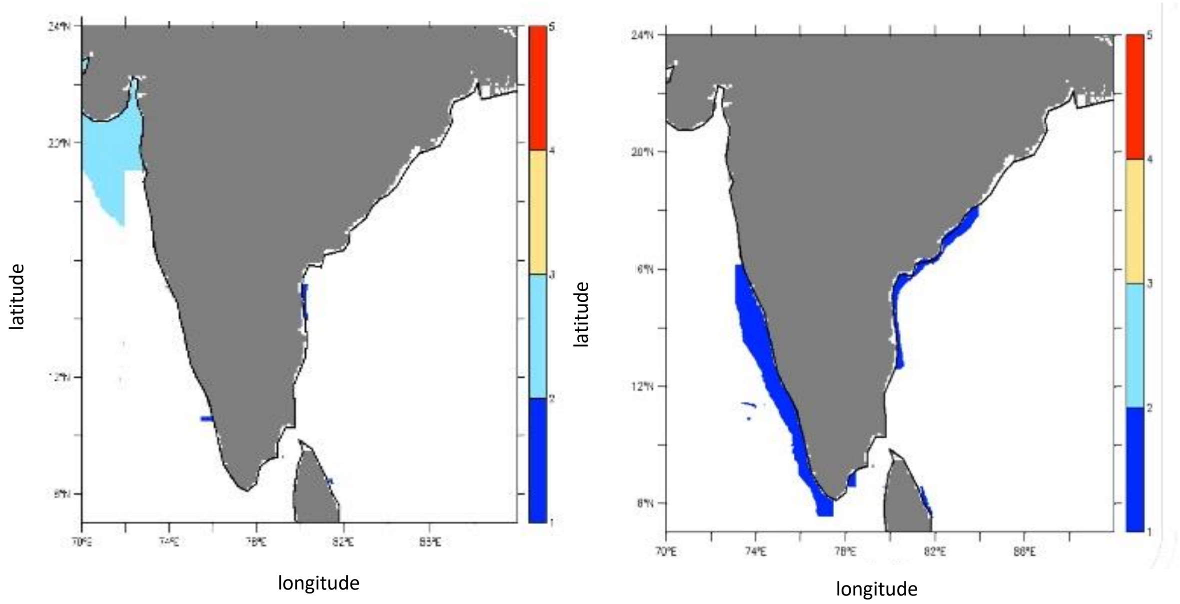
This case study (Mini *et al*, 2015) describes the development and use of a GIS-based multi-criteria analysis for identifying suitable sites for cage culture by incorporating remotely sensed data sea temperature, Wind velocity, Bathymetry, Tidal currents and Salinity.

In this study GIS based multi-criteria analysis (MCA) is a method for decision support in the context of spatial environment. A MCA model contains a set of evaluation criteria which are quantifiable indicators of the extent to which decision objectives are realised. In this study optimal / near optimal sites MCA was carried out using QGIS to identify appropriate locations for cage culture based on a group of factors and constraints. Factor and constraint layers are detailed in the hierarchical modelling chart. The factor indices were converted into polygon to centroid layers and the distance matrix computed. Based on the distance matrices and suitable Min/ Max functions optimal points were zeroed in on and plotted as themes in map. For the listing of critical favourable bio-physical parameters the ones quoted in Rao *et al* (2013) were utilised in the study. The resultant maps indicating favourable zones during the predominant seasons of the country are given below.

Pre Monsoon



South-West Monsoon North-East Monsoon



The case study threw up some interesting findings along with the routine ones which are specific to Indian coast. The seasonal drift is more pronounced during South–West monsoon, which makes some sort of consistency of zones for eight remaining months. Hence planning may be done suitably for candidate species. This type of study includes the most crucial of the near-coastal parameters like wind and tidal currents which makes the resultant zones protected against major risks of loss of infrastructural capital. Salinity and temperature are two parameters which form the interface between the physical and chemical oceanographic phenomena which in effect decide the candidate species and their net growth rate. As a way forward, these remotely sensed parameters can be coupled with prospective marine GIS cum market intelligence data in future for zooming in on specific safe spots for commercial cage installation.

References

Vásquez-Quispesivana, W., Inga, M. and Betalleluz-Pallardel, I., 2022. Artificial intelligence in aquaculture: basis, applications, and future perspectives.AGRIS, FAO

Omar F. El- Gayar The use of information technology in aquaculture management AQUACULTURE ECONOMICS & MANAGEMENT 1(1-2):109-128 · MARCH 1997

Ronald Pelot and J.P. Cyrus Optimization of a large-scale scallop hanging culture operation EUROPEAN JOURNAL OF OPERATIONAL RESEARCH 115(1):1-18 · FEBRUARY 1999

Yin-Han Wang, Richard Turton, Ken Semmens and Tatiana Borisovna (2008) Raceway design and simulation system (RDSS): An even based program to simulate the day-to-day operations of multiple-tank raceways, Aquaculture Engineering, 39, pp 59-71

Yang Liu, Sei-Ichi Saitoh, I. Nyoman Radiarta, Hiromichi Igarashi and Toru Hirawake (2014) Spatiotemporal variations in suitable areas for Japanese scallop aquaculture in the Dalian coastal area from 2003 to 2012 Aquaculture (422-423) pp: 172-183

Mini K.G., Grinson George, J. Jayasankar, Sathianandan, T. V., Somy Kuriakose and Phiros Shah, 2015. Site Selection for Open Sea Cage Culture using Spatial Analytics. Presented in the *5th International Symposium on Cage Aquaculture in Asia*, 25-28 November 2015, Kochi, India.

Rao, G. Syda and Imelda, Joseph and Philipose, K. K. and Mojjada, Suresh Kumar (2013) Cage Aquaculture in India. Central Marine Fisheries Research Institute, Kochi.

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