A MODEL FOR THE OPTIMUM LOCALIZATION OF AQUIFEROUS FARMING IN PONDS: THE CASE OF THE ATACAMA REGION - CHILE

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SUMMARY

It is very well-known the important contribution that the aquaculture industry generates to the Chilean economy. However, although the localization of the cultivation centres can be decisive in the success of an enterprise of this type, in Latin America there is a scarce use, of the modern tools based on the Geographical Information Systems (GIS) for this. This article shows the use of this tool to ponder several critical factors in the determination of the optimum localization of aquiferous cultivations in ponds in the coastal border of the III Region of Atacama, Chile. The results show that the optimum areas for aquaculture based on cultivation ponds are centred in three sectors that coincide with areas near the three main ports of the Region: Chañaral, Calsera and Huasco.

KEY WORDS: Aquaculture, site selection, Atacama, Geographical Information Systems (GIS)

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INTRODUCTION

A favourable climate and a very ample wide coast make the III Region an appropriate place to develop some types of aquiferous activities, which has been the cause of the installation of several cultivation centres in the coastal border of the region; these have been devoted to produce molluscs and algae. The molluscs cultivations develop their activity based fundamentally on the Northern Oysters, the Pacific Oyster (or Japanese) and the Green Abalón (or Japanese), while the algae producing centres have been devoted exclusively to the cultivation of the "Pelillo" (Gracilaria). According to the registrars of the National Fishing Service, this Region in 2000 had 32 Aquiculture Centres (18 of Molluscs and 14 of Algae) which produced a total of 7,809 tons.

The need to search for new horizons for this productive sector has impelled a constant development of innovation projects, as in the incorporation of new processes technologies, as to the expansion of the range of species, which means to have a tool that helps to select new places apt for aquaculture. In this research a procedure is developed that allows to facilitate the aquaculture enterprises to select new sectors on the coastal border of the III Region, considering exclusively the geographical aspects, although it is recognized that this kind of decisions can involve several considerations of another type.

For this, one worked with the following approaches and decision: access to seawater, compatibility with the Coastal Intercomunal Regulator Plan, land gradient, road accessibility, and manpower and electricity availability. Through a series of spatial analyses one reached a final map, which highlighted the optimum areas for the location for cultivation systems on land.

METHODOLOGY

The study is developed for the cultivation systems on land placed on the coastal border of the Chilean III Atacama Region. The methodology developed in this study is applicable for the Land Cultivation Systems, (Pond), which implies being relatively near the coast, contrary to the cultivation systems in the sea (see Annexe that contains a listing of feasible species that can be cultivated in the coastal border).

The analysis tool used is a Geographical Information System (GIS) that can be defined in simplified terms, as a useful system databases administration, to store to read and to manipulate data, which allow to carry out sophisticated spatial and visual analysis by means of several routines (see for example Burrough, 1986). The GIS appear as from the 70's as an answer to the growing demand of spatial analysis required by the main United States public services. Previously these analyses were carried out in manual form through big transparencies placed on an illuminated table. As the analyses became more complex, the traditional methodology began to show its practical restrictions. With the arrival of computers, the efforts began to digitalize these procedures. Today the GIS programs are very powerful and costs have lowered and are now accessible to most of the public services and universities[1].

Other studies which have used the GIS tool in aquaculture are for example Kapetsky et al. (1988) who analyzed the localization of areas for the aquiferous development of the catfish *(Ictalurus punctatus)* in Franklin Parish, Louisiana. Ali et all, (1991) carry out a similar analysis for the cultivation of carp species in Pakistan. Also Ross et al. (1993) apply GIS for the cultivation of salmon in Scotland. The FAO (1992) has also elaborated a work document in which GIS applications are analyzed and the

1 The ArcView 3.2a programme, developed by ESRI (Environmental Systems Research Incorporated), was used in this study, which is highlighted by the SIG world standard. Its native format, the shape or SHP, is imported and exported by practically all the SIG programmes.

teleperception in continental fishing and the aquaculture, thus providing a revision of a series of case studies.

CRITERIA FOR OPTIMUM LOCALIZATION

Previously it was commented that the selection matrix is based on 6 criteria, those that conform to the matrix used for the selection. Each one of these criteria generates a certain area or covering that is apt, according to that criteria.

1) Areas Compatible with the Intercommunal Regulator Plan

The III Region has the Atacama Coastal Communes Regulator Plan which clearly describes which are the appropriate uses of the land, and there, there are the general dispositions that define the urban, rural and protected areas, the road layout and the specific regulation per area. Within the specific regulation, there is the expansion area. Area ZUI 6 (ordinance article 34) which eventually could be destined to the support in land of traditional and aquaculture fishing activities and the so called Environmental Protection Zone, (In Spanish ZPA), which have several restrictions, and whose origins go from the preservation of the environment up to the presence of natural risks, those that should be discarded as areas apt for aquaculture installation. Figure 1a shows a sample of the Environmental Protection Zone.

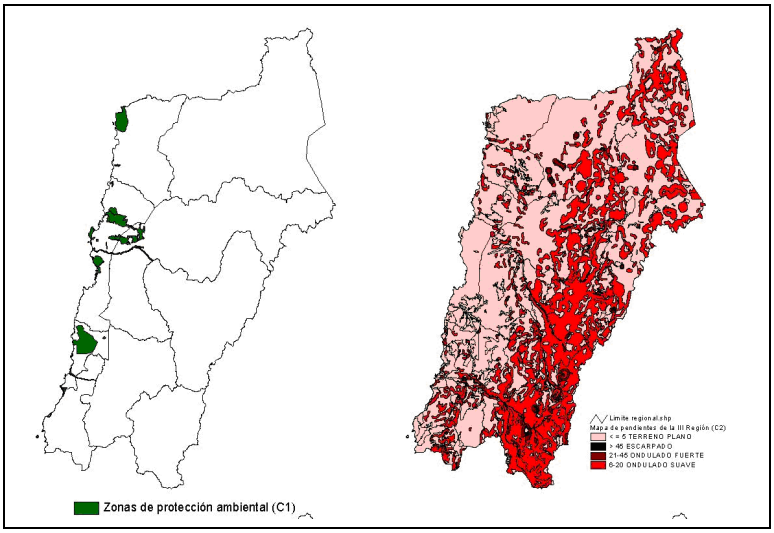
2) Areas with Gradients Capable for the Construction of Infrastructure

The installation of constructions and ponds and aquiferous equipments in areas with little gradient, reduce the costs of use of the lands for this concept. That is why those sectors, whose gradients were less than 5 degrees, were selected. Figure 1b shows the polygons that represent sectors with different gradients.

Figure 1

Environmental Protection Areas (a)

and Areas with Apt Gradient (b)



3) Coastal Roads Network and Quality

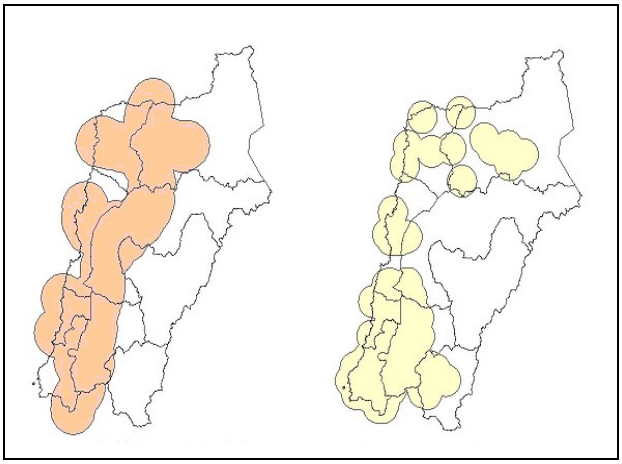
The access roads network to the productive centres as well as their quality, are outstanding factors when installling an aquiferous cultivation due to the fact that it will always be necessary to transport inputs, personnel and of course the exit of the final product. A greater distance to a main road impacts strongly in the rise of operation costs. For this reason an area of influence of 30 Km was built, around the covering of main roads. With this the polygonal covering C9, was created, which assures the selection of places with good road accessibility. Figure 2a shows a buffer of several kilometres around the main roads of the region.

4) Manpower Availability: Populated Centres

To assure that there will be enough manpower available for the operations of a cultivation centre, one requires that the selection place be near the main populated centres. For this a 20 Km area of influence was built, around the main populated centres, which generates a polygonal covering of areas with accessibility to manpower according to Figure 2b.

Figure 2

Coastal Roads Network (a) and Populated Centres (b)



5) Electricity Availability

The proximity to electricity networks reduces the costs significantly as to the operation of pumping equipment and water circulation in the ponds, illumination and other matters, regarding the alternative operation of autonomous electricity generation. For this reason an area of influence of 20 Km., was generated. Around the current electricity networks, to be able to generate a polygonal covering that defines the

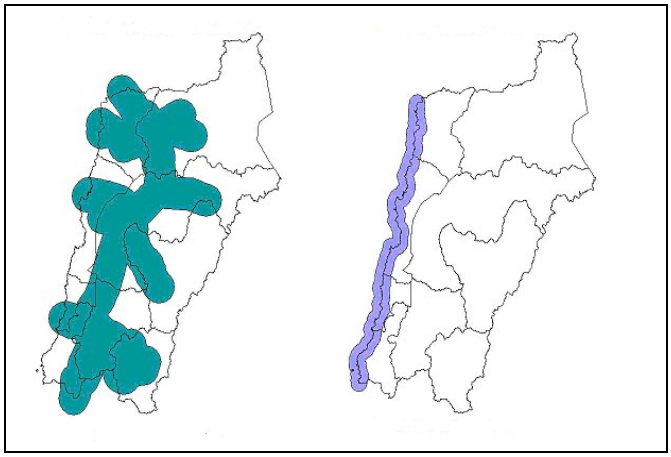
sectors with better disposition to have access to the electric network, as shown in Figure 3a.

6) Seawater Availability

To assure that the selected land is sufficiently near to the sea, a covering was generated based on the coast of the III Region, through an influence area of 10 Km., thus creating a polygonal covering according to Figure 3b.

Figures 3

Electricity (to) and Seawater (b) Availability



RESULTS

The selection process consists on identifying those geographical localizations in which the 6 criteria, mentioned beforehand, are fulfilled. As a result three sectors were determined according to Figure 4.

The Chañaral Sector corresponds to the sector located more to the north of the III Region, and it corresponds to the surroundings of the city of Chañaral[2]. To the north of Peralillo, to the south of Caleta Barquillo and to the south Punta Infieles, there exist areas that are excluded from the selection, for corresponding, in the first case, to an "ecological protection zone" (ZPI-2), the second one a "a diverse use zone (ZUI-1) and an industrial intercommunal zone (ZUI-4) and in the third case a "populated centres support zone" (ZUI-7), according to the Atacama Coastal Communes Intercommunal Plan. Also, to the north of Chañaral a sector was excluded because it does not fulfil the gradient requirements of < 5°.

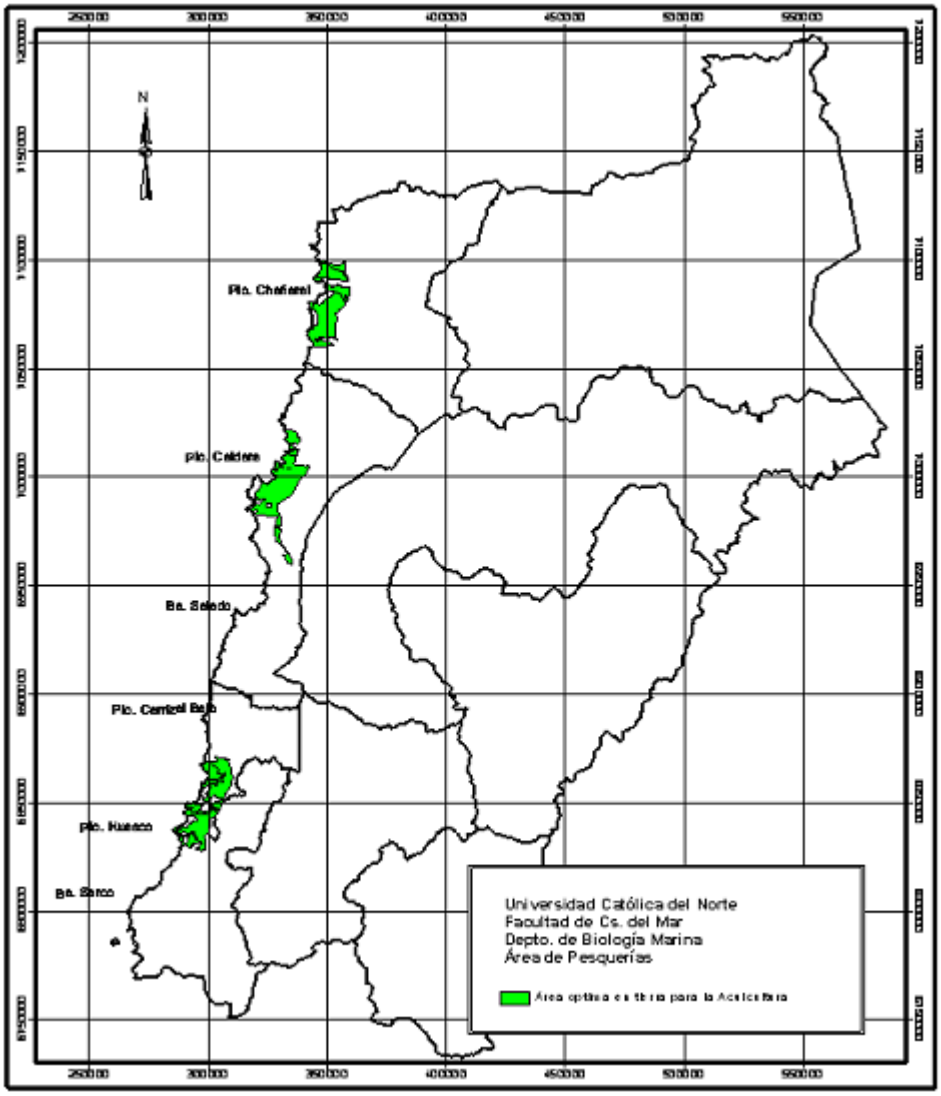
The Caldera Sector is located in the centre of the III Region, and it corresponds to the surroundings of the city of Caldera. One can observe that to the south of Bahía Inglesa there is an area that is excluded, because it correspond to an "ecological protection zone (ZPI-2)", according to the zoning carried out in the Atacama Coastal Communes Intercommunal Plan. Indeed, the possibility is visualized there of installing an area of marine reservation from Punta Morro till Bahía Cisne.

Finally the Huayco Sector appears, located to the south of the III Region, and corresponds to the surroundings of the city of Huasco. One can observe that south of Los Toyos until Punta Negra and from Punta Negra until Huasco there are areas that are excluded from the selection for belonging, the first case to a "tourist development zone (ZUI-5), and in the second case to a "River Huasco protection Zone (ZPI-3)", according to the zoning carried out in the Atacama Coastal Communes Intercommunal Plan. Finally, to the south of southern Punta Huasco, there is an excluded area because its gradient does not fulfil the requirement of being < 5°.

2 This well known environmental problem, generated by the mining relaves in front of the coast of this sector, which makes it non viable to cultivate in the sea. However there is an alternative to use sea water to carry out cultivation on land, which must be evaluated scientifically to determine the presence of substances non compatible for aquaculture.

Figure 4

Selection Matrix Final Map



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ANNEX

In order to define optimum localizations, a listing of aquiferous species that can be cultivated in ponds, placed, in the coastal border of the III region was made. According to the development degree reached in technology and to the transfer degree, to the productive sector, these species (native and introduced), can be classified in 4 stages: commercial (if one knows the cultivation technology and it is applied currently), pre-commercial (the cultivation technique is known, but the costs are still too high for economic viability to exists), pilot and experimental, according to the following Chart.

Species cultivable in the III Region Coastal Border.

According to Development stage of the Cultivation Technology

Stage	Species
Commercial[3]	Japanese Abalón (Haliotis discus hannai), Red Abalón (Haliotis rufescens), Turbot (Scophthalmus maximus)
Pre-commercial	Red Hedgehog (Loxechinus albus)
Pilot	Chilean Sole (Paralichthys adspersus), Hirame (Paralichthys olivaceus)
Experimental	Clam (Venus antiqua), Knife (Ensis macha), Navajuela (Tagelus dombeii), European Oyster (Pecten maximus), Limpets (Fissurella spp.), Locate (Thais chocolata), Crazy (Concholepas concholepas), Macha (Mesodesma donacium),

3 In the commercial stage there are 6 cultivated species in the sea, (not in ponds). North Ostion (Argopecten purpuratus), Chilean Oyster (Ostrea chilensis, Cholga (aulacomya ater), Choro Zapato CGhoromytilus chorus) Japanes Oyster (Crassostrea gigas) and Pelillo (Gracilaria chilensis)

	Octopus (Octopus spp.), Snail Trumulco (Chorus giganteus), Golden or palometa (Seriola lalandi), Sea Pejerrey (Odontesthes regia), Red Conger (Genypterus chilensis), Corvine (Cilus gilberti), Chascón (Lessonia nigrescens), Huiro (Macrocystis integrifolia), Huiro (Macrocystis pyrifera), sea Chicoria (Chondracanthus chamissoi), Black Luga (Sarcothalia crispata) and Red Luga (Gigartina skottsbergii).

However, as the fundamental restrictive in the selection of a resource to be cultivated commercially is the degree of availability and consolidation in cultivation technology until the adult phase (it puts on weight), the localization analysis should only be cantered in those species that only belong to the commercial groups.