Title: A GIS SUPPORTED DIAGNOSTIC OF RIO DE JANEIRO AQUACULTURE PRODUCTION CHAIN AND ITS IMPLICATIONS FOR DEVELOPMENT

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Application Tool: GIS. (SPRING 3.5 and ArcView 3.0).

Main Issues Addressed: Strategic planning for development.

The general problem, or aim of the study, and the contribution of GIS, remote sensing and/or mapping to the solving the problem: The state of Rio de Janeiro has recognized its potential for aquaculture development through the years. Several native and exotic species are cultured in its diverse climatic conditions which range from warm subtropical to sub-temperate in the higher altitudes present in the state's mountainous areas.

A state-wide evaluation of its aquaculture potential was carried out using a combination of digital maps integrated with map layers digitised for this study, through a GIS assisted model. The study allowed the identification of regions with higher potential for implementation or expansion of different types of aquaculture.

Main Environments: Brackishwater and Inland.

Culture Systems: Ponds; Raceways.

For the species considered in this study, culture systems are briefly described, with local productivity figures obtained during interviews with producer associations, extension agents and technicians. These figures were used in the final discussion based on table 8.

Coastal earthen ponds:
For marine shrimp culture in the coastal zone. Geometrically shaped ponds, with supplemental aeration provided by paddle wheel aerators, at a rate of 2 - 6 HP/ha. Oxygen levels maintained at 3.0mg/l minimum. Feed supplementation with complete formulated extruded feed., under semi-intensive culture conditions. These include artificial aeration provided by paddlewheel aerators, and feeding complete artificial formulated feeds. Production estimate: 2,000 kg/ha/yr

Inland earthen ponds:
Several species are suited for tropical and sub-tropical climates over inland areas of Rio. Fish culture is generally carried out under semi-intensive regime, in earthen ponds. Stocking rates are low, pond aerators are rarely employed, and in most cases only supplemental feeding is supplied. Main species in order of importance are Tilapia, Tambaqui, Pacu, Piraptinga, and their hybrids. Altitudes considered in the modelling are lower than 300 m. Average production estimates, supplied by FIPERJ and EMATER-RIO (extension services) are 5700 kg/ha/yr for tilapia and 4300 kg/ha/yr for Tambaqui, Pacu, Piraptinga, and their hybrids.

Concrete raceways:
Rainbow trout in raceways, usually at elevations over 600 m. Lowest productivity considered by local trout farming association assuming all farms and areas in production. Production estimate: 72,000 kg/ha/yr.

Floating longlines:
For Brown mussel, Mangrove oyster – Pacific oyster, and native scallop. In coastal waters sheltered from the Southwest. Mussels on longlines, oysters and scallops may be suspended from longline in 'lanterns'. Productivity: Mussels: 1,000 kg of mussels per longline system comprised of longlines 50m in length, with vertical lines spaced 1 m apart between rows and longlines separated 2 m apart from each other. 25% dressout rate. Based on interviews with mussel growers in Ilha Grande. 1,150 dozen Pacific oysters per 50m longline spaced 2 m apart. Lantern culture system. Based on mean data from growers in Ilha Grande. 600 dozen scallops per 50m longline spaced 2 meters apart. Lantern culture system. Based on mean data from growers in Ilha Grande. Production estimate: 25,000 kg/ha/yr. Productivity estimates: Mussel 25,000 kg/ha/yr, Oysters 115,000 kg/ha/yr and Scallops 60,000 kg/ha/yr

Intertidal racks:
Mangrove oyster and Pacific oyster. In coastal waters sheltered from the Southwest. Oysters in polyethylene bags lying on racks in the intertidal zone. Rack support are usually made with bamboo or alternatively hardwood. Production estimate: 115,000 kg/ha/yr.

Flooded stalls:
North american bullfrog – is cultured indoors. Intensive rearing production system is known as 'flooded stall'. Usually a building with a center corridor and two long and shallow pools with support for boardwalks where frogs can protect themselves under, or alternatively bask. Frogs are fed complete specifically designed feeds, and water in the stalls is regularly exchanged. Additional supplemental feeding with chopped bovine lungs may be furnished. Production estimate: 75,000 kg/ha/yr based on EMATER-RIO frog growers survey of 1999 – (unpublished data).

Organism Divisions: Crustaceans, Freshwater fishes.

Genera and Species:

Scientific name	Common local name
Colossoma brachypomum	Pirapitinga
Colossoma macropomum	Tambaqui
Crassostrea gigas.	Pacific oyster
Crassostrea rhizophora	Mangrove oyster
Litopenaues vannamei	White shrimp
Nodipecten nodosus	Scallop
Onchoryncus mykiss	Rainbow trout
Orechromis niloticus	Tilapia
Perna perna	Brown mussel
Piaractus mesopotamicus	Pacu

Target Country: Brazil.

Target Audience: Potential investors in rural/coastal areas with aquaculture potential. Local business chambers, municipal planners, farmers, aquaculturists, consultants, rural/ fisheries extension agents, researchers, technical consultants.

Duration of the Study and Year Begun: Seven months, 2001.

Personnel Involved:

Table 1. Function, personnel, and time spent on the case study.

Disciplines/functions	Personnel	Duration
SEBRAE – supervisor/ coordinator	Lídia M. Espindola	7 months
Scientific Coordinator, GIS planning	Philip C. Scott	7 months
GIS specialist – data processing	Luiz Fernando Vianna	7 months
Field data collection and processing	Marco Antonio de C. Mathias	7 months
Field aquaculture data collection	Pedro Paulo Oliveira	30 days
Field aquaculture data collection	Augusto Pereira	30 days
Wholesale and retail data collection	Roberto Roche Moreira	30 days
SEBRAE - data collection support	Silvia Pereira Reis	7 months
Retail and restaurant data collection	Paulo Cesar Dantas Esteves	30 days

A GIS SUPPORTED DIAGNOSTIC OF RIO DE JANEIRO AQUACULTURE PRODUCTION CHAIN AND ITS IMPLICATIONS FOR DEVELOPMENT

Introduction

Aware of the growing economic importance of farmed aquatic species in the Rio de Janeiro state, its market and furthermore, of the development potential, SEBRAE/RJ promoted the current study, aiming at identifying those elements capable of guiding all interested stakeholders including producers, retail and wholesale merchants, rural and fisheries extension agents, researchers, technical consultants and new investors. The study was also to determine the state's overall aquaculture potential and point out regions most indicated for siting aquaculture production systems in municpalities across the state.

SEBRAE/RJ, (Serviço de Apoio às Micro e Pequenas Empresas no Estado do Rio de Janeiro) is a mixed company (government/private) service organization with a mission to support small business development.

SEBRAE/RJ linked up with LAQUASIG – Aquaculture and GIS Lab of the Biological and Environmental Sciences Institute of Universidade Santa Úrsula, in a partnership to develop a GIS study entitled "Diagnóstico da Cadeia Aqüícola para o Desenvolvimento da Atividade no Estado do Rio de Janeiro". This was carried out by a multidisciplinary group (Table 1) under the coordination of Philip C. Scott. The study results were presented to the public on June 17, 2002.

Materials and Methods

GIS software used in this study, were SPRING v. 3.5 and ARC VIEW v. 3.0. SPRING software is freeware, a GIS developed by INPE, the Brazilian Space Agency. To study the problem on a state-wide basis, a base map, was built by patching a mosaic of 24 sheets of digital maps on a scale 1:100,000 and 22 maps on a scale of 1:50,000 produced by Fundação CIDE, of Rio de Janeiro. The dataset included a climatic layer (CIDE, 1996, scale of 1:500.000). Vector layers included roads network, principal wholesale marketplaces, environmental conservation areas, rivers and streams, main topographic divisions, climatic regime, mean annual temperature. No direct use of satellite images was employed, although landuse and vegetation type interpreted from satellite imagery was incorported (source: CIDE). Thematic layers used in the modelling included landuse, vegetation types, environmental units (geology, geomorphology, soils and ecossystems) and climate layer. A restrictive layer was developed which included the environmental protection areas of the state, as well as urban areas. These layers were used at the end of the model for exclusion.

For each theme (production functions) a weight varying between 0 – 10 was attributed, according to its relative importance to the culture system conisdered: trout, shrimp, tropical fish, frog or mollusc farming (Tables 2, 3, 4, 5, 6 and 7). The weights were attributed on the basis of the experience of members of the group and discussion about the relative importance of each factor in relation to each species culture. For the shrimp model a landward limit of up to 2000 m from the coastline was used. For the mollusc model a seaward limit of up to 300 m from the coast was used.

Table 2. Relative weights attributed to land use classes identified in base maps.

Land use classes	**Weights**			
	Shrimp	Fish	Trout	Frog
Secondary vegetation	10	10	10	10
Forests	0	0	10	0
Rocky outcrops	0	0	0	0
Farmland	10	10	10	10
Prone to seasonal flooding	6	8	4	8
Urban Áreas (high density)	0	0	0	0
Urban Áreas (medium density)	0	0	0	0
Urban Áreas (low density)	7	7	8	7
Fields/ Pastures	10	10	10	10
Highland fields	0	0	10	0
Eroded hilsides	0	0	8	0
Forested steppes	0	0	8	0
Seasonal forests	0	0	9	0
Major constructions	0	0	0	0
Mangroves	0	0	0	0
Mangroves, Degraded	9	9	0	0
Beaches	0	0	0	3
Forestry projects	0	0	10	0
Sandy beach vegetation	5	5	0	10
Water bodies	0	0	0	0
Salt evaporation ponds	7	0	0	0
Exposed soils	8	8	3	6
Lowlands	10	10	10	10

Table 3. Relative weights attributed to air temperature (°C) classes for aquaculture.

Air temperature classes		**Weights**			
		Shrimp	Fish	Trout	Frog
Hot	(>24)	10	10	0	10
Warm	(15 – 18)	8	8	0	8
Cool	(10-15)	0	3	0	0
Very cool	(10)	0	0	1	0

Table 4. Relative weights attributed to reclassified land cover classes.

Soil type/vegetation cover classes	*Weights*			
	Shrimp	Fish	Trout	Frog
Fluvial deposits	8	8	0	8
Coluvium	0	3	0	3
Mangroves	0	0	0	0
Mountains	0	0	10	0
Hills	0	0	0	6
Foothills	0	3	0	9
Sandy beach vegetation	9	6	0	3
Water bodies	0	0	0	0
Loose/ clayey soils	10	10	0	10
Hill sides	3	8	6	6
Unclassified	0	0	0	0

Table 5. Relative weights attributed to relative air humidity classes.

Water deficit classes - dry months/yr		*Weights*			
		Shrimp	Fish	Trout	Frog
Very Dry	(11-12)	10	0	0	0
Dry	(7 – 10)	10	0	0	0
Semi-humid	(4 – 6)	10	10	0	10
Humid	(1-3)	10	10	10	10
Super-humid	(0)	10	10	10	10

Table 6. Relative weights attributed to distance (km) from road grid.

Weight	Limits
10	< 10 km of a paved road
8	< 10 km of a paved road and < 5 km of a secondary route
5	< 5 km of a secondary route

Table 7. Relative weights attributed to distance (km) from main cities/markets.

Weight	Limits
10	> 250
9	200 – 250
8	150 – 200
7	100 – 150
6	50 - 100
1	< 50

The model was organized and values attributed in the Model Builder module of ArcView 3.2 (Figure 1, Figure 2 and Figure 3). In the modelling, the vector layers were rasterized keeping their respective weights. Each raster layer map was attributed a value between 0–10 according to its importance for each culture species. The aptitude map was calculated by a mean weighted module and again presented in a 1–10 scale, where 0 stands for the unsuitable areas, and 10 the most suitable. These classes were then regrouped into 4 classes: Most Suitable, Suitable, Moderately Suitable and Unsuitable.

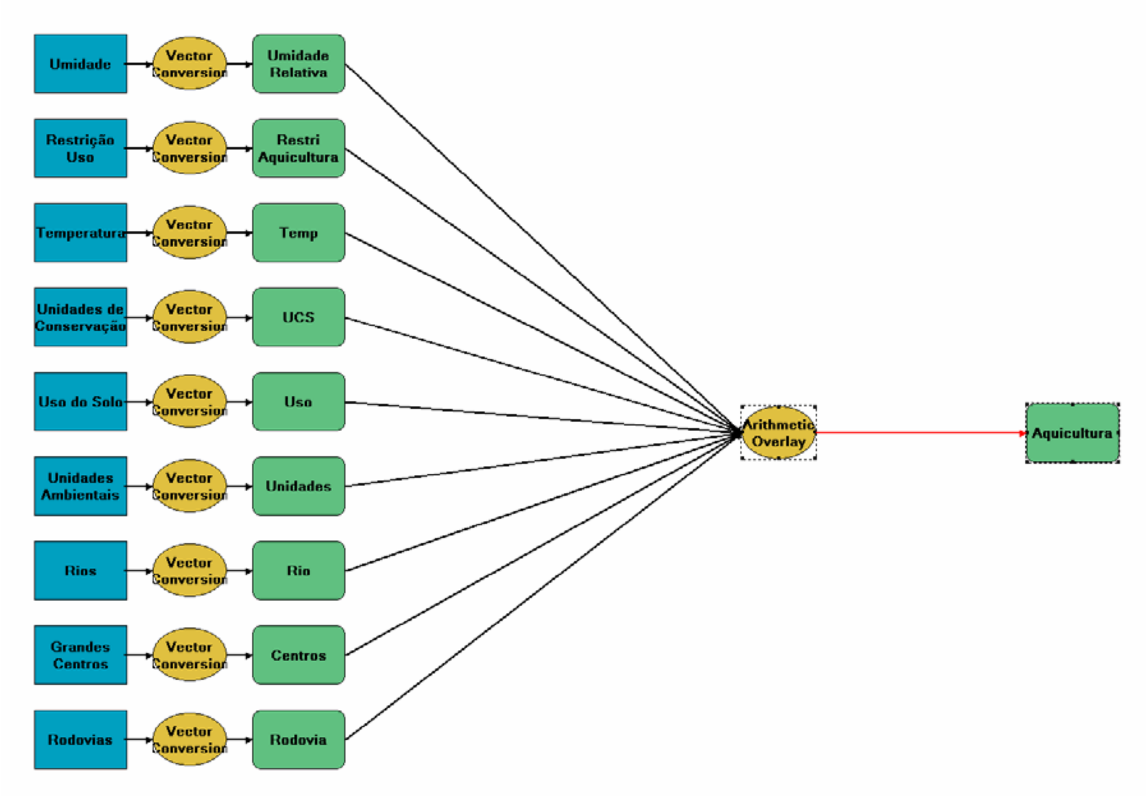

Figure 1 Model Builder module of ArcView 3.2 for Aquaculture.

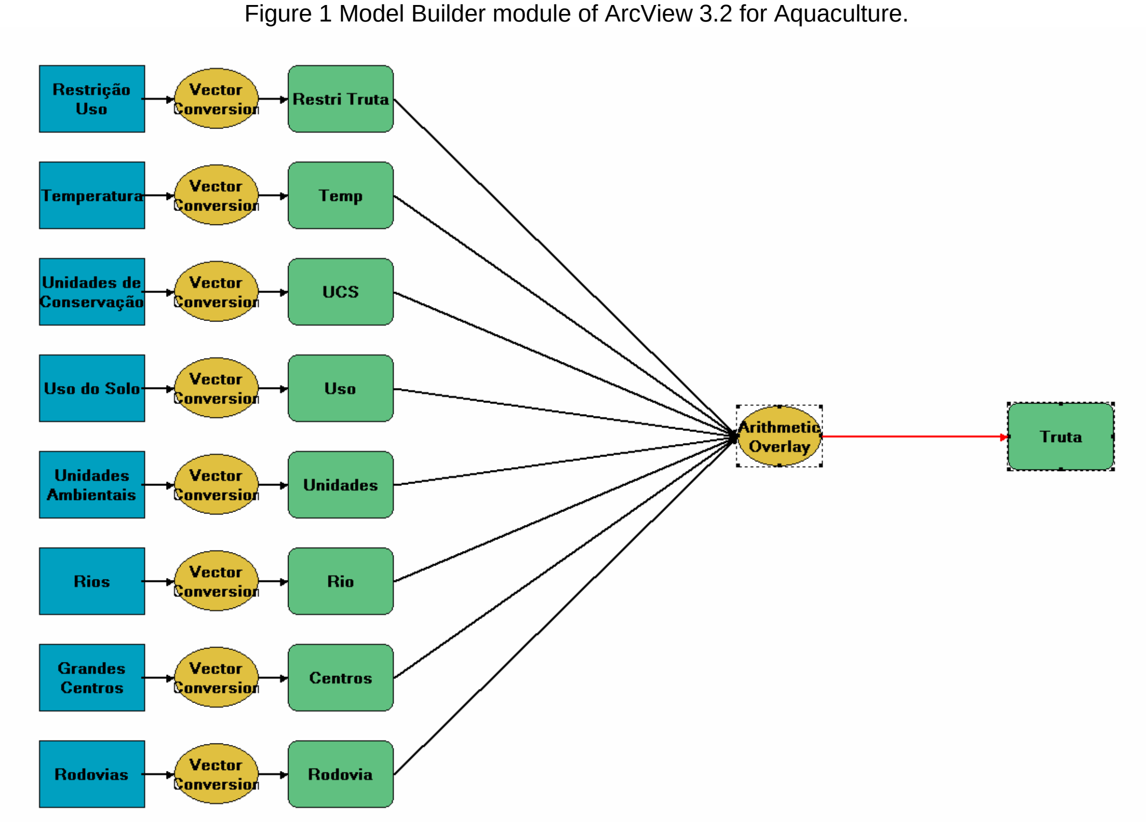

Figure 2 Model Builder module of ArcView 3.2 for Trout Aquaculture.

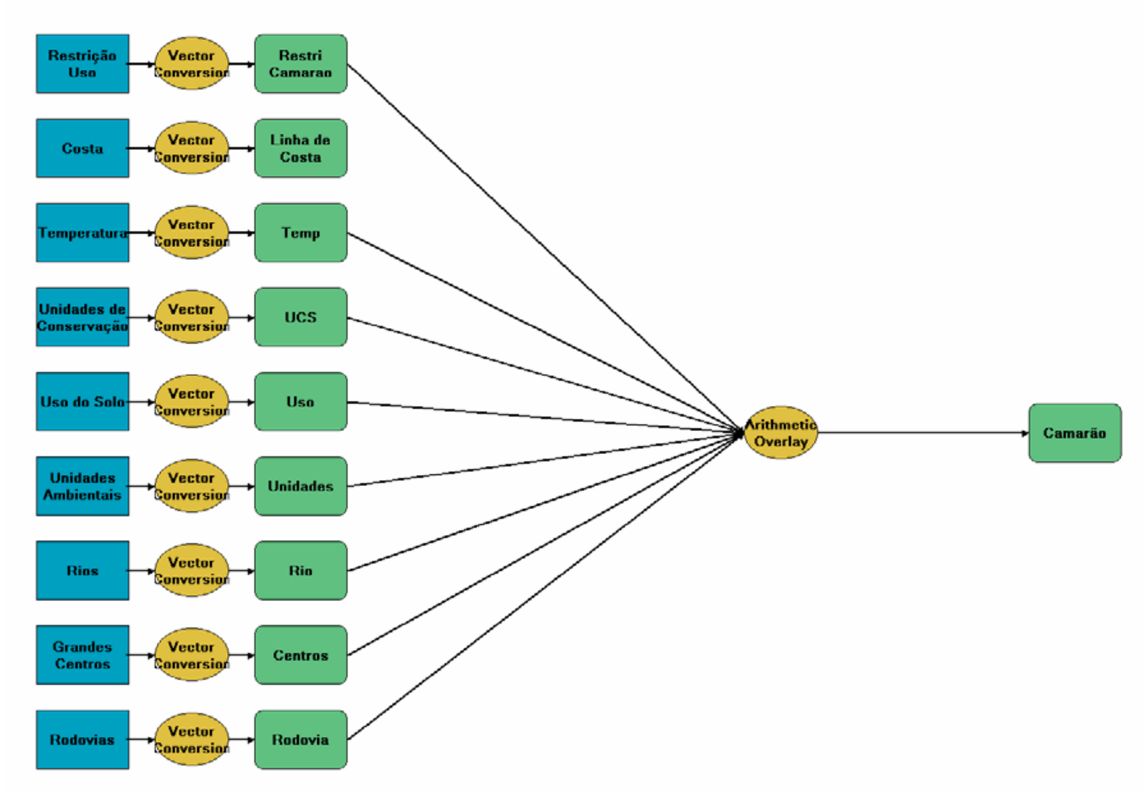

Figure 3 Model Builder module of ArcView 3.2 for Shrimp Aquaculture.

Results

The results of the modelling are presented in three maps (Figures 4, 5, 6) in the scale of 1: 500,000.

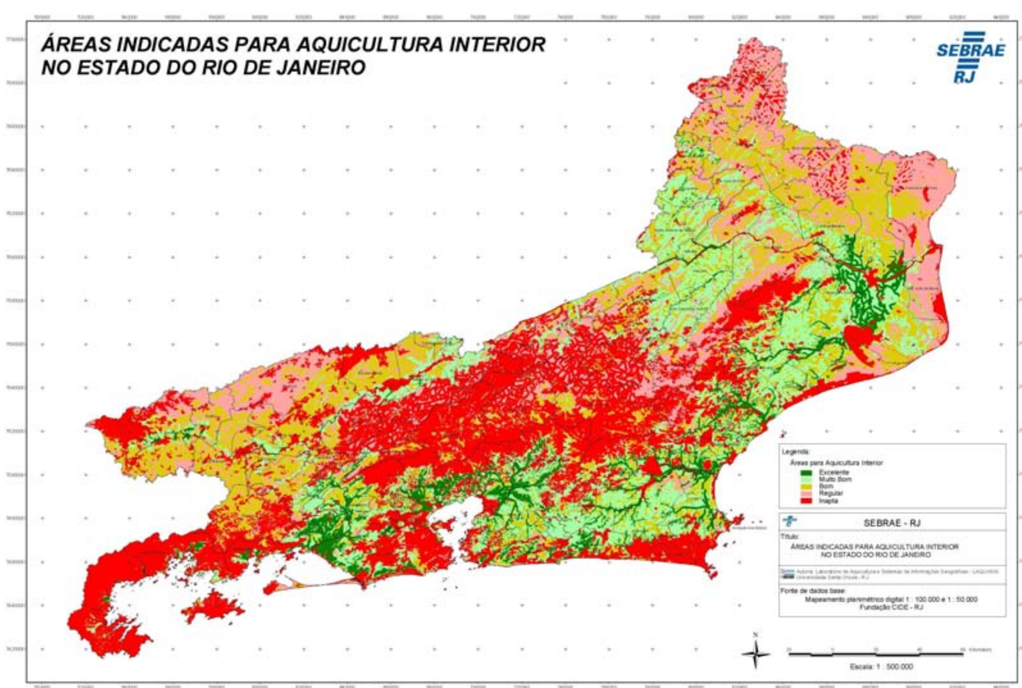

Figure 4. Suitability for tropical freshwater fish farming.

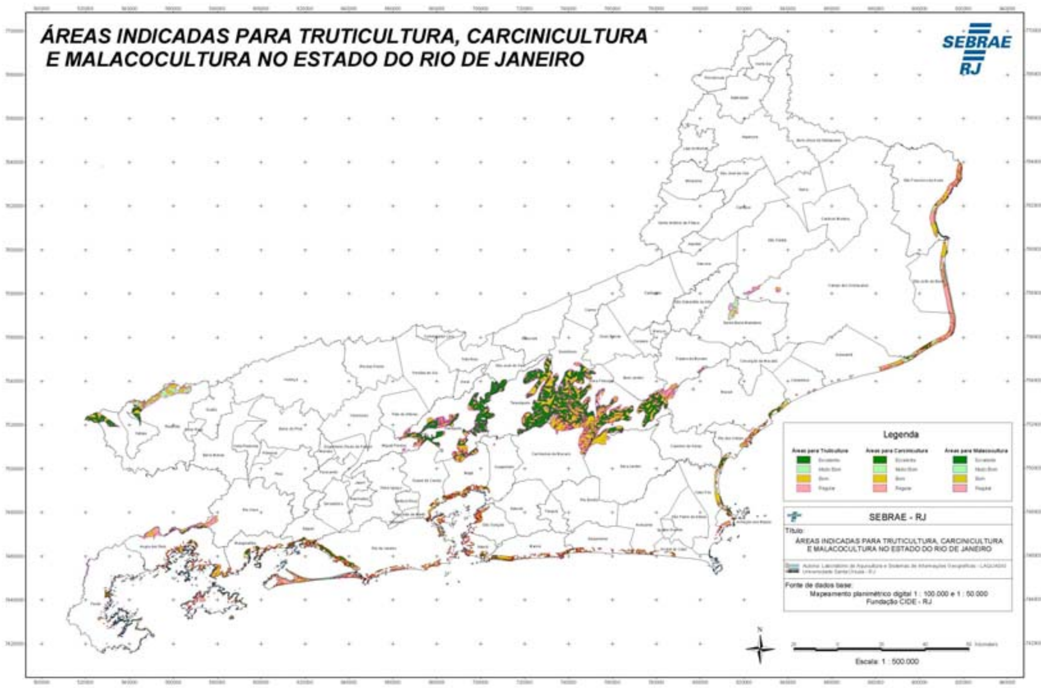

Figure 5. Suitability for shrimp, bivalve molluscs and trout farming.

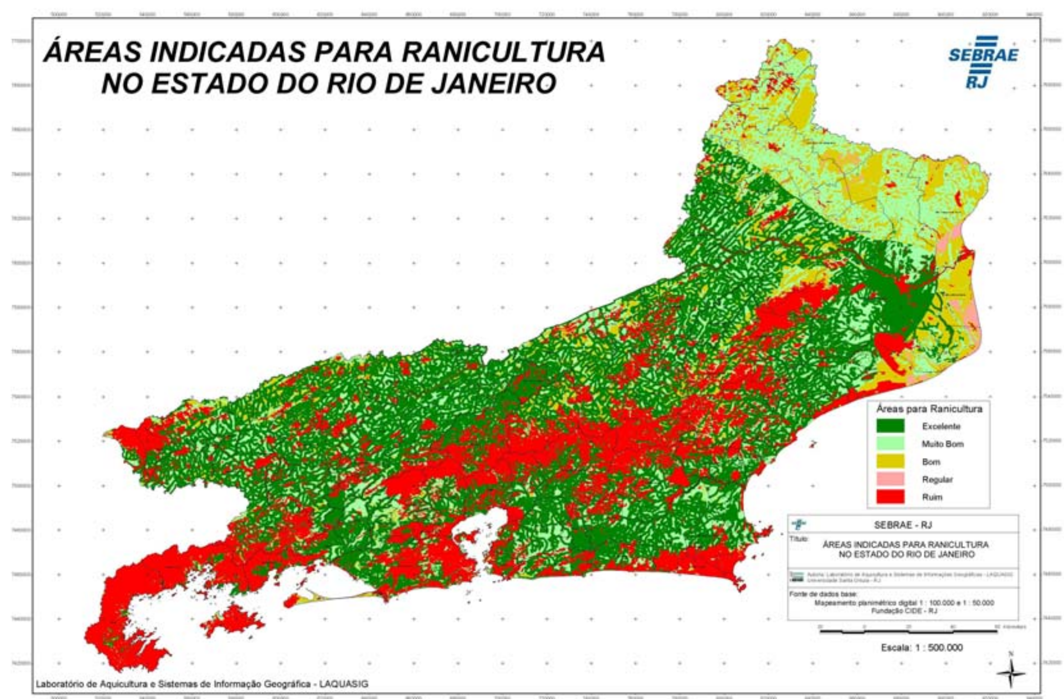

Figure 6 Suitability for frog farming.

The results and consequences are summarised in Table 1.

Discussion

In this GIS study, a pragmatic approach was used in order to confront aquaculture development potential detected in the GIS modelling viz a viz current aquatic product demand detected from interviews in the three principal wholesale seafood markets of Rio de Janeiro.

With the exception of marine shrimp, all other aquatic species (warm water species of fish, rainbow trout and frogs) are already farmed in many areas of Rio de Janeiro. The productivity of each species was assessed by interviews with farmers and fisheries extension agents familiar with the culture sytems and practices. For marine shrimp, which is currently not cultured in Rio, a lower productivity level than that usually obtained in Northeastern Brazil was used.

In order to maximize the potential use of the GIS for the study and analysis, a further step was taken. The potential total suitable areas identified for each species was confronted with the perceived demand detected during the interview phase in the markets study. In this way, for each aquaculture commodity, (shrimp, mussels, oysters, clams, frogs, rainbow trout and warmwater fish) the production area (ha) needed to meet the current perceived demand for the state was identified.

Furthermore, having identified the current demand from the market survey, as well as the percentage of suitable site areas needed to make Rio de Janeiro self-sufficient in relation to demand, a priority index was established in order to rank the most sought after commodity in relation to the least amount of area available for its culture. These results are summarised in table 8.

Table 8. Summary o GIS modelling results for Rio de Janeiro potential and demands.

Commodity	**Estimated Productivity** (kg/ha/yr)	**Suitable areas** (ha)	**Area needed to cover demand** (ha)	**Percent of suitable areas needed to make state self sufficient**	**Priority Index (PI) to cover aquaculture products in the state**
Marine shrimp	2,000	47,331	264	0.5578	0.8355
Tilapia	5,700	2,060,189	29.5	0.0014	0.0933
Tropical fish	4,300	2,060,189	20.1	0.0010	0.0636
Mussel	25,000	16,448	1.9	0.0117	0.0061
Oysters	115,000	16,448	0.1	0.0008	0.0004
Scallops	60,000	16,448	0.04	0.0002	0.0001
Trout	72,000	161,115	0.3	0.0002	0.0008
Frogs	75,000	3,186,768	0.06	0.0000	0.0002

(Marine shrimp = *Litopenaeus vannamei*. Tilapia = Red varieties and hybrids of *Oreochromis niloticus*. Tropical fish = *Colossoma macropomum*, *Piaractus mesopotamicus, Colossoma brachypomum* and hybrids. Oysters = *Crassostrea rhizophorae.* Scallops = *Nodipecten nodosus*. Trout = *Oncorynchus mykiss*. Frogs = *Rana catesbiana*).

Comment on the verification of the GIS, remote sensing or mapping results

Proper validation of the model's results was not feasible for this study. Funding for this study was limited. However, to add some form of verification to the model outputs, meetings with colaborators in the fisheries and rural extension services were held, where discussion of the outcomes of the model using the suitability maps generated, subjectively assessed their plausibility. The outcome was positive, and experienced extension agents were able to pinpoint areas where the activity does in fact occur, in a satisfactory manner, and thus agrees with the model's outputs. Other areas of aquaculture potential identified by the models were discussed in the context the feasibility of their development. Under the current conditions of financial and planning resource limitations, the SEBRAE experience using the available map database integrated in a GIS was regarded as very constructive by all participants.

The results indicate that with a relatively small number of hectares turned into production, the state of Rio de Janeiro could be self sufficient in its aquaculture commodity demands. The largest area needed would be that for marine shrimp, where less than 300 ha of ponds would suffice. By using a Priority Index (PI), the study also showed that the highest development priority is for marine shrimp, currently imported from other states. The PI also served to show participants the relative importance of each commodity in the context of local markets, and feed discussions about the adequacy of aquaculture development policies so far implemented.

References

Scott, P.C., Vianna, L.F. & de Campos Mathias, M.A. 2002. Diagnóstico da Cadeia Aqüícola para o Desenvolvimento da Atividade no Estado do Rio de Janeiro – *Panorama da Aqüicultura*, 12(71): 15–25. In Portuguese. Summary – (Diagnostic of the Aquaculture Production Chain and implications for its development in Rio de Janeiro, Brazil). http://www.alternex.com.br/%7Ephilip/sebrae.pdf

Scott, P.C. Vianna, L.F. & de Campos Mathias, M.A. 2002. 223 pp. Diagnóstico da Cadeia Aqüícola para o Desenvolvimento da Atividade no Estado do Rio de Janeiro - SEBRAE. (com mapas). Full report, In Portuguese. (Diagnostic of the Aquaculture Production Chain and implications for its development in Rio de Janeiro, Brazil)

Scott, P.C. & Vianna, L.F. 2001. SIG: Determinação de Áreas Potenciais para a Carcinicultura. *Panorama da Aqüicultura,* 11(63): 42–49. In Portuguese. (GIS-RS- assisted GIS site selection of potential sites for shrimp farming). http://www.alternex.com.br/%7Ephilip/carcini.pdf

Scott, P.C. & Ross, L.G. 1998. O Potencial da Mitilicultura na Baía de Sepetiba. *Panorama da Aqüicultura*, 8 (49): 13–19. In Portuguese. (Mussel culture potential for Sepetiba Bay). http://www.alternex.com.br/%7Ephilip/mytilus.pdf

Scott, P.C. 1998. GIS-assistedConsiderações sobre o uso da Baía de Sepetiba, RJ para Maricultura apoiadas num Sistema de Informação Geográfica (SIG). Relatório USU N0. 98.001 V2. In Portuguese. (Considerations on the use of Sepetiba Bay for mariculture, based on a Geographical Information System). http://www.alternex.com.br/%7Ephilip/USU98001V2.pdf

Scott, P.C. 1996. Sistemas de Informação Geográfica para Aqüicultura. *Panorama da Aqüicultura,* 37 pp.