AN EXAMPLE OF GIS POTENTIALITY FOR COASTAL ZONE MANAGEMENT : PRESELECTION OF SUBMERGED OYSTER CULTURE AREAS NEAR MARENNES-OLERON (FRANCE).

Durand, H.,
GUTLAR/LCT ENGREF-CEMAGREF 361, rue J.F. Breton 34033 Montpellier France

Guillaumont, B., Loarer, R., Loubersac, L.,
IFREMER Groupe SILLAGE Centre de Brest BP 70 29280 Plouzané France

Heral, M., Prou, J.,
IFREMER DRV/RA CREMA L'Houmeau Pl. du Séminaire BP 5 17137 La Rochelle France

Abstract

The Charente Maritime coast, in central western France, is the most important area for oyster and mussel production in Europe. High density, in this restricted intertidal area, induces low growing rate and socio-economic difficulties. One of the possible solutions is to shift some oysters from intertidal area to submerged areas.

Bathymetry, sedimentology, hydrodynamism, fisheries and administrative rules are some conditions which are considered to establish the better selection of potential zone.

The successive steps of setting up the prototype of GIS are presented : digitized traditional data from charts, extracted data from grid models (hydrodynamic model), merging of thematic covers, proposal of favorable areas.

The results are discussed especially on the points where spatial analysis methodologies have to be improved : crossing methodologies between grid and vector formats and aggregation of layers. Some ways of research are presented, particularly the improvment of some techniques issued from artificial intelligence (possibilities theory, fuzzy logic).

1. Introduction

Due to increasing demographic pressure along the coast, and thus a particularly vulnerabled and restricted space, conflicts between diverse activities arise. These activities can be traditional or contemporary, continental or maritime, industrial, urban, touristic, agricultural, fisheries or marine farming.
In order to make decisions, managers need more information about environmental caracteristics, as well as the distribution of the activity, constraints and compatibility analysis.
The existing information comes from various origins and sectorial studies which make gathering data difficult.

The aim of this report is to analyse the methodological problems which occur during the management of plurithematic information, keeping it spatially coherent, crossing it to produce synthetic and easily accessible results and testing differents scenarii.

The Charente Maritime coast, in central western France (Fig. 1) has a concentration of numerous activities. This site was choosed to develop a tool to aid in decision making.

This area is the most important area for oyster production in Europe. The production occurs in a restricted intertidal area (Marennes-Oleron Basin) that induces low growth and high mortality rates. The cost production is now higher than in others european production basins. This results in socio-economic difficulties for this traditional and regionally important activity. Among the possible solutions to these problems, one is to shift some oysters from the intertidal area to submerged areas nearby. This practice has already been successfully conducted in an another site along the Brittany coast.

Such a solution presuppose the ability to estimate the potentialities, in relation with submerged oyster cultivation constraints, of the bottoms and to analyse the space disponibility.
The intention is to find a site around 2000 hectares. Fisheries and tourism are other important activities. The Charente Maritime region is the second most visited area in France and La Rochelle is the most popular european pleasure boat harbour. In this region, competition for space and dense population are acute problems and have to be taken into consideration for coastal management purposes.

A preliminary demonstration model for a decision-making tool, has been developed by a geomatic team, using ARC-INFO software and in collaboration with oyster culture specialists. This model is dedicated to the preselection of areas favorable to submerged oyster culture.

In this study successive steps necessary for building such a tool are presented :

- analysis of submerged oyster cultivation constraints,

- analysis of available data,

- numerical data acquisition formatting and structuring into a Geographical Information System,

- crossing methodology and potentiality coefficient development,

- preliminary result analysis and interactive scenarii development.

Lastly, a critical examination of the preliminary model is made and thematical, as well as technical improvements, are suggested.

2. Méthodology

2.1. Analysis of submerged oyster cultivation constraints, available data

2.1.1. Analysis of submerged oyster cultivation constraints

In such a culture, the oysters are spread out upon the bottom surface and dredges are used to harvest.
Some environmental conditions are necessary to respect biological and exploitation requirements:

- bathymetry must be situated between 4 to 25 meters,

- a flat bottom, not too hard to use a dredge but not a fluid mud either,

- low hydrodynamism near the bottom to avoid the scatter of oysters and a production loss,

- good water quality (no pollution, good productivity) and no trophic competition with Marennes-Oleron shellfish farming.

Space competition with other activities must be estimated :

- Regulations have to be taken into consideration. The majority of them concern navigation contraints (harbour approaches, maritime roads). Because of the lack of sea surface equipment, with the exception of pleasure boat traffic, low impact upon tourist activities is assumed.

- The mussel and seaweed long line cultures take up small areas. Fisheries are spread over large areas. Depending on the fishing mode used, they will interfere more or less with oyster cultures. The use of trawls will be inconsistent with this activity.

- The most important areas of ecological value, like spawning grounds and nurseries, have to be also taken into consideration.

2.1.2. - Analysis of available data

The topographic maps from the Institut Geographique National (IGN) give us access to the coast line and toponymy at different scales (1/25 000 to 1/100 000). The projection used is Lambert 2 (ellipsoïde de Clarke 1880).
The bathymetry is indicated as isobaths (0, 2.5, 5, 15, 20 30 m...) and soundings marked on navigation charts from the Service Hydrographique de la Marine (SHOM) at differents scales (1/46 500 ..). A Mercator projection is used(ellipsoïde de Hayford 1929).
Some topographics and bathymetric data are available as digital data (high cost).

Different thematics maps are available from various sources with different scales and projections :

- biosedimentary unit maps (Hily, 1976),

- shellfish farming areas and fisheries (IFREMER, DDE Charente Maritime),

- spawning grounds and nurseries (CEDRE 1986, IFREMER, DDE Charente Maritime),

- navigation, fishing and salubrity administratives rules, (SHOM, Affaires Maritimes, DDE Charente Maritime).

Other data can be extracted from models. Physical parameters are generally computed on grids (.5 to 2 km), but biological models use boxes.
The main models and data available are :

- A model from LHF-IFREMER can generate amplitude and direction of the swell, particularly the annual swell (Fig. 2). A wave model is also available.

- Different models developed at LCHF (1979) and IFREMER can simulate the intensity and direction of currents. Residual currents (Fig. 3) and maximum currents at the bottom are very interesting parameters. An hydrosedimentary model is in development (Raillard et al. 1994).

- A primary production model from IFREMER (Raillard, O., 1991) enable us to estimate the primary production on boxes (for exemple annual primary production).

All these data are generated as numeric data but in various formats.

2.2. Organisation of data.

The 1/100 000 IGN topographic map is used as a reference map. This scale correspond to the required accuracy.
A standard pattern has been defined for every document produced in the demonstration model (Fig. 4 and 5).

2.2.1. Numerical data acquisitions.

The first step of this study was to digitize all the data from different charts. This was done using ARC-INFO ADS menu.
Some of the data could be treated directly : all administrative or used regulation documents (for example the limits of the navigation channel or the existing oyster farming sites on the coast). Others data had to be analysed to reduce the complexity of the existing document.
all the data derived from a model were treated using a numerical display output in one of the cases (for example the maximum swell). This continuous data (ex : hydrodynamic, currents) which comes from raster analysis have been merged in a small number of classes. The Digital Numeric Model comes from bathymetric lines and sample points used in a Triangular Irregular Network (TIN) interpolation with a 100 m^2 pixel.

2.2.2. Data structuration in relation with submerged oyster culture constraints.

Taking into account submerged oyster cultivation constraints, each thematic layer is partitioned (Tab. 1) into different classes : very favorable, favorable, unfavorable or excluded areas. They can result from an interpolation procedure, manual interpretation or value setting (Fig. 6), aggregation, primary layer derived product or cover crossing. Each class correspond to an attribute value (from 2 for very favorable to -1 unfavorable ; 99 is assign to excluded area and 0 to neutral layers).

2.3. Potentiality coefficient determination

2.3.1. Merging of thematic covers

the different thematic layer were intersected to obtain a large synthetic cover. The intersection was made using the command UNION successively in order to retain all the items and all the associated arcs of the different layers. At the end of this step, the small polygons with an area less than the accessible precision are eliminated. Thus, polygons with an area under one hectare and perimeter under a certain limit were merged with their neighbor, except for the small oyster site polygons on the coast. This problem comes from the vector form analysis. This synthetic cover enables to calculate a global index wich takes into account all the different thematics.

2.3.2. Preliminary results.

We calculated the global index in three steps. in fact we are not able now to classify the relative importance of each thematic parameter. Several questions need to be addressed :

- Are the physical caracteristics more important than economic one's?

- Are the different fisheries activities so important that they must be analysed separately or could we put them in a unique global fisheries activity?

We chose to develop three indexes which correspond to threee levels of constraints :

- One analyses the synthetis of the physical environment.

- A second is a synthetis of environmental potentiality and regulation.

- The third takes into account the first two points along with economic activities and ecological constraints (Fig. 7).

The results of this classification is the following :

- Concerning the physical environment : 42% of the area is available (32 280 ha) and 9 223 ha is very favorable to oyster farming.

- Taking into account regulations : 32% of the Pertuis is still available (24 594 ha).

- Taking into account the physical, regulation, economic and ecological constraints, 6148 ha is very favorable to oyster farming.

2.3.3. Interactive procedure

These initial conclusions can be discussed. The future users could decide to emphasis one constraint more than another. Using Advanced Macro Language (AML) of ARC INFO, we built a menu in order to enter some ponderations which can be applied to each thematic value. This menu was developed with an " user friendly " interface and displays statistical results and maps, allowing for an unlimited number of scenarii immediatly.

3. Critical analysis and improvement proposals

This type of approach allows us to clearly identify decision parameters and rules of tool. Lack of information is clearly evident. The interactive tool makes an estimation of their qualitative and spatial importance possible.

The data used in coastal areas are particularly heterogeneous (different projections, scales or origins). Some of them are generated, or can be analysed on vector form. However a large part of data taken from a model or representative of continuous information, are generated from or would be better represented in a raster form.

This preliminary demonstration model must be improved in different ways :

- utilisation of more adequate or complete thematic data,

- thematic improvement in the knowledge of incompatibility between activities,

- technical improvements in data management, and in partitioning and merging methodologies.

3.1. Thematic analysis

The use of isobath data and punctual soundings appear insufficient, particularly in producing derived data such as slope. Rough sounding and geostatistic interpolation procedures will enhance the results.
The sediment units can be defined using complementary data sets. A hydrosedimentary model, still under development, will be able to deliver turbidity and bottom erosion/deposition grid data. The risk of oyster drift can be simulated using bathymetry, swell, current and wave models.
The primary production model has a limited extension which is at the moment not sufficient to introduce in the model, the use of remote sensing data sets could be used to classify the water types.

Socioeconomic information is insufficient. Administrative limits must be digitalised. The value of the different fisheries, and not only the area concerned, must be determined, as well as the estimation of other possibilities (extension of mussel or seaweed cultures for example).
The production cost, in various conditions, has to be estimated.
The ecological and economic impact between the different activities have to be precised.

3.2. Technical and methodological analysis

Some improvements are necessary in data base elaboration regarding precision, spatial coherence and a multiscale approach.
Spatial analysis procedures can be introduced to take into consideration vicinity constraints.
The resulting representations have to be enhanced for better communication.

But, a critical point concerns the structuring of continuous data. This is particularly accute in marine and costal environments because most of the parameters have a gradient distribution and pertinent synthetic information can be extracted using grid model.
As a matter of fact, it is easy to use vector procedures to take into consideration information such as administrative regulation limits. However, it is more difficult to discrete continouous data, for example bathymetry. Such an operation requires delimiting a homogeous areas, introducing artificial thresholding. For a continuous parameter, a favorable criteria element would probably have a better representation with a gaussian curve than with discrete threshold. The raster to vector transformation induces approximations. The successive crossing of such parameters enhances errors.
The lack of information in a small area is difficult to manage in this procedure.

Using artificial intelligence technologies is one interesting perspective. Data imprecision like "the area is favorable to oyster culture up to 25 +/- 5m depth" can be managed using fuzzy logic. Concept like "probable", "possible", "certain", and uncertainty due to user's subjectivity can be handled using possibilities theory.

Even if this preliminary demonstration model is dedicated to the preselection of submerged oyster culture sites, many data sets or reasoning steps could be generalized and applied to the management of other coastal applications. Interactive and evolutionary tools for testing scenarii seem also essential.

In the long term, it will be necessary to introduce 3-D and temporal data management and also to connect with continental models and GIS (as for exemple those established on the Charente river).

It appears that marine and coastal S.I.G., as well as decision-making tools need many specific developments and flexible equipment.

Aknowledgements

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Data sets : Affaires Maritimes, CEDRE, DDE Charente Maritime and LCHF
M. Forest, P. Le Hir and O. Raillard (IFREMER).
A. Freeman

References

CEDRE, 1986, "Atlas régional pour la protection et la lutte contre les pollutions accidentelles venant de la mer : Atlas de Charente Maritime", CEDRE DPNM 84.26.00.

DDE Charente Maritime, 1993, "Le livre bleu : Shéma de Mise en Valeur de la Mer", DDE Août, 1993.

Hily, C., 1976, "Ecologie benthique des Pertuis Charentais", Thèse de 3° cycle, Université de Bretagne Occidentale 1976.

L.C.H.F., 1979, "Dispersion de la pollution dans les Pertuis Charentais", Rapport technique général L.C.H.F.

Raillard,O., 1991, "Etude des interactions entre les processus physiques et biologiques intervenant dans la production de l'huitre *Crassostrea gigas* (Thunberg) du bassin de Marennes-Oleron : essai de modélisation", Thèse Université de Paris VI, 27 Mars 1991.

Raillard, O., Le Hir, P. et P. Lazure, 1994, "Transport de sédiments fins dans le bassin de Marennes Oleron : mise en place d'un modèle mathématique", *La Houille Blanche*, N°4.

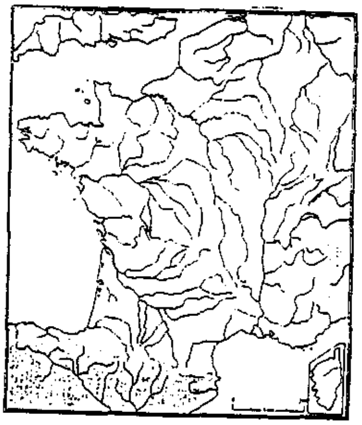

Fig. 1 Pertuis Charentais and Marennes-Oleron Basin map localisation

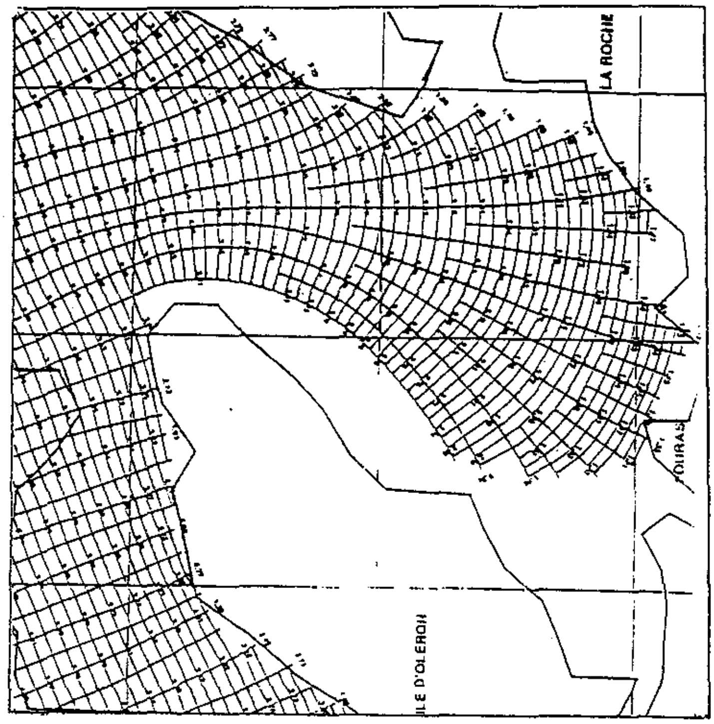

Fig. 2 Amplitude and direction of swell (annual swell). Rough data extracted from model. (LHF-IFREMER)

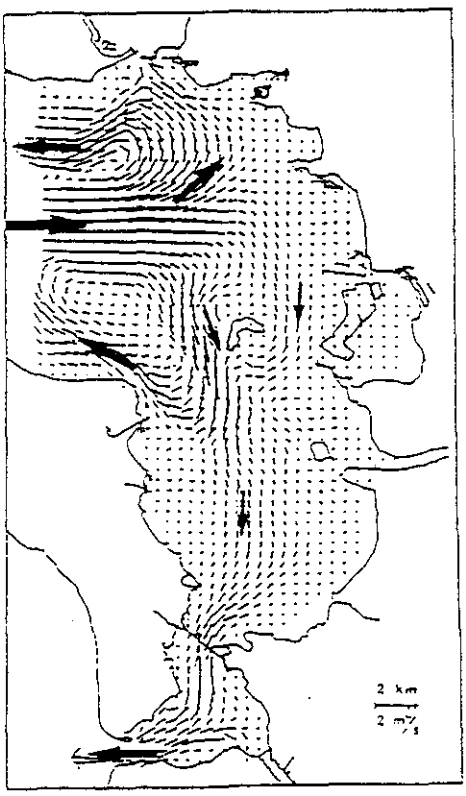

Fig. 3 Residual current rough data extracted from LCHF hydrodynamic model

Theme	Constraints	excluded area 99	Unfavorable -1	Neutral layer 0	Favorable 1	Very favorable 2
Environmental caracteristics						
Bathymetry (z)	4 < z < 25m				+	
	z < 4m	+				
	25m < z	+				
Slope	< 2 %				+	
	> 2 %	+				
Sediment type	mud/muddy sand				+	
	gravels/sands		+			
	rocks	+				
Swell (h) /bathymetry	h < 2,5 et 4 < z				+	
	2,5 < h < 4 et 10 < z				+	
	4 < h et 15 < z				+	
	others conditions	+				
Maximum current	< 1 m/s				+	
	> 1 m/s	+				
Residual current	seaward					+
	middle condition				+	
	toward Marennes-O. basin		+			
Primary production				+		
Administrative						
Navigation	channels	+				
	others				+	
Right of way	submarine cables	+				
	others				+	
Salubrity	insalubrious harbour areas	+				
	others		+			
Fishing regulation	trawl, scallops		+			
	others				+	
Areas of ecological interest						
Spawning grounds	all species		+			
	absence				+	
Nurseries	all species		+			
	absence				+	
Fisheries and marine farming						
Marine farming	long lines	+				
	others	+				
Fisheries	trawls		+			
	fishing-pot, fishing nets			+		

Tab.1 Thematic constraints matrix of submerged oyster culture (Pertuis area)

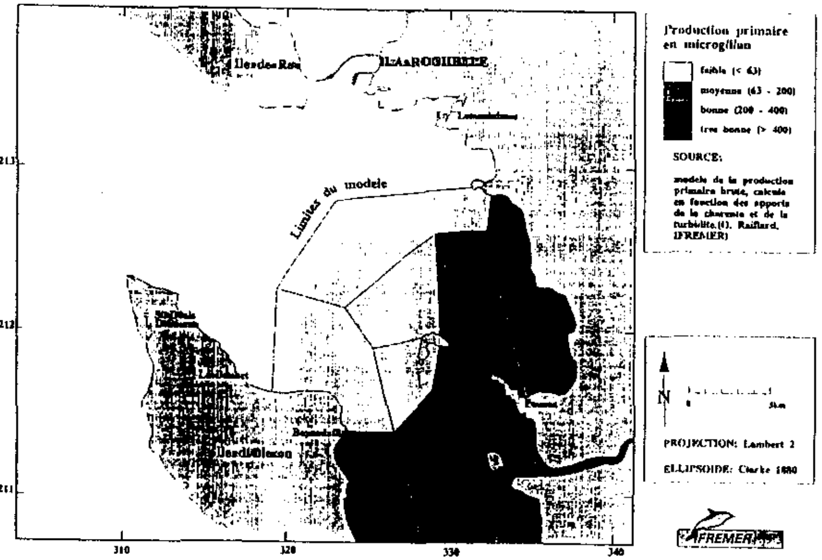

Fig. 4 Primary production (µg/l/year)
Data extracted from model

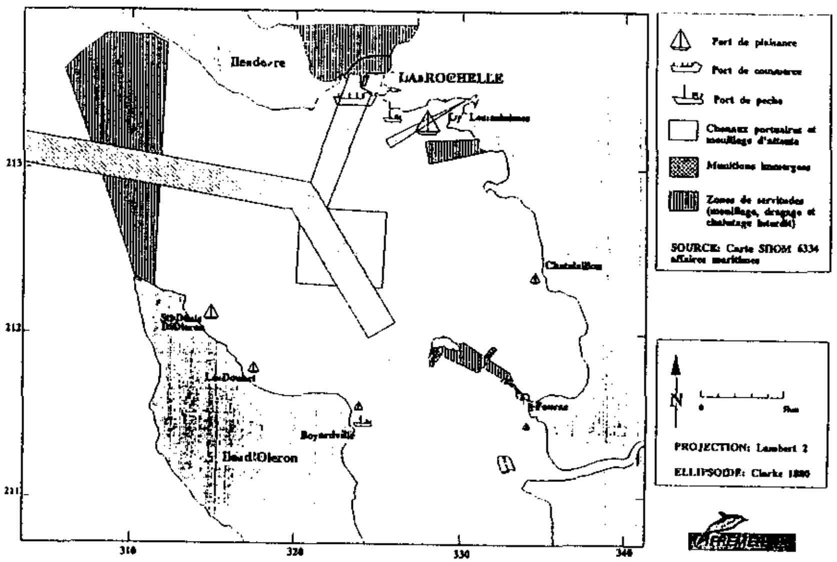

Fig.5 Regulations (navigation,military areas, submarine cables...)

Fig.6 Bathymetric classes (excluded or favorable areas). Submerged oyster cultivation constraints.

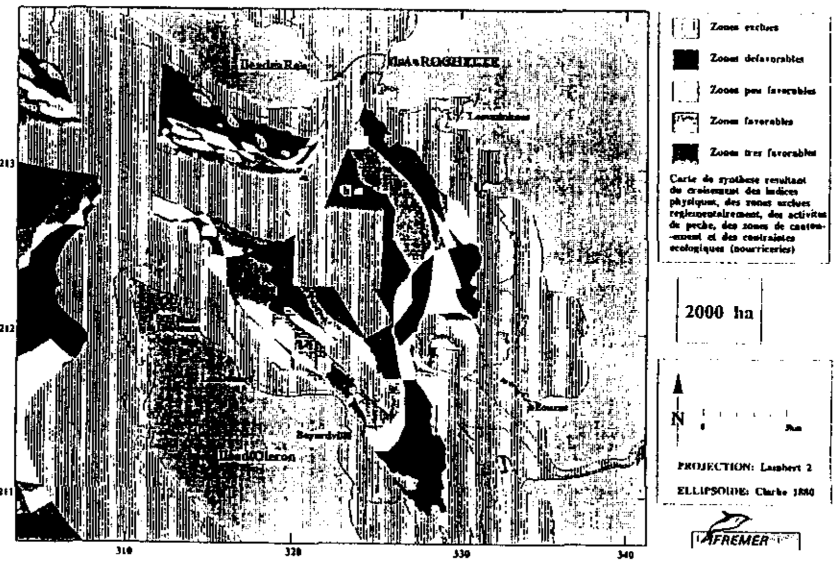

Fig. 7 Global index (physical,regulation, economic and ecological constraints).