SITE SELECTION FOR BRACKISHWATER AQUACULTURE DEVELOPMENT AND MANGROVE REFORESTATION IN LINGAYEN GULF, PHILIPPINES USING GEOGRAPHIC INFORMATION SYSTEMS[1]

J. N. Paw
D.A.D. Diamante
N.A. Robles
Chua T.-E.

International Center for Living
Aquatic Resources Management (ICLARM)
MC P.O. Box 1501, Makati
Metro Manila, Philippines

and

L.N. Quitos, Jr.
A.G.A. Cargamento

National Economic and Development Authority
Region I Office
San Fernando, La Union, Philippines

Abstract

Brackishwater aquaculture production in Lingayen Gulf in northwestern Luzon, Philippines is one of the highest in the country. Most of the fish farms are mangrove forest and marginal lands which have been converted for milkfish and shrimp culture. Brackishwater aquaculture development has been closely associated with mangrove forest denudation. In recent years, the ecological importance of mangrove forest has been recognized, especially as nursing and feeding grounds for many aquatic species. This understanding has led to efforts in mangrove reforestation and conservation.

Are there potential sites for brackishwater aquaculture expansion in the Lingayen Gulf? A site selection study using geographic information system (GIS) showed about 16,000 ha of potential sites that excluded major agricultural land uses and mangrove reforestation areas. For mangrove reforestation, about 12,000 ha have been identified. The results of this study are as yet preliminary and further work is needed to determine the actual potential sites.

For poster presentation at the
Canadian conference on GIS - 1992
24-26 March 1992, Ottawa, Ontario
Canada

---

1 ICLARM Contribution No. 784.

RECHERCHE DE SITES POUR L'AMENAGEMENT AQUACOLE EN EAU SAUMATRE ET POUR LE REBOISEMENT DES MANGROVES DANS LE GOLF LINGAYEN, PHILIPPINES A L'AIDE DES SYSTEMES D'INFORMATIONS GEOGRAPHIQUES

Résumé

La production aquacole dans les eaux saumâtres du Golf Lingayen, au Nord-Ouest de l'île de Luçon, Philippines, est l'une des plus importantes du pays. La plupart des fermes aquacoles sont établies dans des forêts de mangroves et sur des terres marginales converties pour l'élevage des chanidés et de la crevette. Ces dernières années toutefois, des terres agricoles (rizières) ont également été converties pour l'élevage de la crevette.

Le développement de l'aquaculture en eau saumâtre est étroitement lié au déboisement des mangroves. Depuis quelques années, on reconnait l'importance écologique de ces forêts, notamment comme aires de reproduction et de nourrissage de nombreuses espèces aquatiques. Cette prise de conscience a mené à ce que des efforts soient réalisés dans le sens du reboisement et de la conservation.

Existe-t-il des sites propices à l'expansion de l'aquaculture en eau saumâtre dans le Golf Lingayen ? Une étude sur la recherche de sites réalisée à l'aide du système d'information géographique (GIS) a révélé l'existence d'environ 16.000 ha de sites potentiels, exception faite des grandes terres agricoles et les sites de reboisement des mangroves. Les données sur les types de sols, la physiographie, l'occupation des sols, etc. ont été évaluées au l'aide du GIS pour choisir les sites de reboisement des mangroves. Environ 12.000 de ces sites ont été identifiés.

Les résultats de cette étude ne sont qu'au stade préliminaire. Des vérifications et l'évaluation sur le terrain des terres non agricoles existantes sont nécessaires pour déterminer les sites potentiels réels où il est possible de développer l'aquaculture en eau saumâtre et de mettre en oeuvre des projets de reboisement de mangroves.

1. INTRODUCTION

The Lingayen Gulf area, located in northwestern Luzon, Philippines, covers the provinces of Pangasinan and La Union (Fig.1). It is one of the top fisheries producers in the Philippines. Brackishwater aquaculture production, mainly milkfish (*Chanos chanos*) and penaeid shrimps contribute about 11% of the national aquaculture production while marine fish landing is about 26%. Most of the fish farms are converted mangrove forest and marginal lands and recently, some agricultural lands (e.g., ricelands).

Brackishwater aquaculture development has been closely associated with mangrove denudation. The remaining mangrove stands are mostly found along the periphery of fishponds, especially in Pangasinan. In recent years, the ecological importance of mangrove forest has been recognized by the government, especially as nursing and feeding grounds for many aquatic species. As a result, the Department of Environment and Natural Resources (DENR) through its regional offices are implementing mangrove reforestation projects in the two provinces.

This preliminary study is part of the development of an integrated coastal area management plan for Lingayen Gulf (ICAMPLG) under the ASEAN/US Coastal Resources Management Project. One of the recommendations of the plan is a zonation scheme for land use and coastal water use such as for artisanal fishing, marine parks,

aquaculture (brackishwater and marine), mangrove reforestation, artificial reefs and agriculture, etc. This zonation scheme will be developed as part of a 2-year GIS Coastal Area Management and Planning Project (GISCAMP) funded by the International Development Research Centre of Canada (IDRC).

2. MATERIALS AND METHODS

Site selection criteria for brackishwater aquaculture, especially for Southeast Asia are based on various works [e.g., Menasveta, 1982; Hechanova, 1982; Khoo and Wuan, 1982; Adisukresno, 1982; Poernomo 1990]. The procedure used in this study, however, is based on spatial data using a GIS software called SPANS. Table 1 summarizes the criteria used in site selection of brackishwater ponds.

Digitized thematic maps such as physiography, soil texture, etc. are at 1:100,000 scale while topographic maps are at 1:50,000 scale. For elevation, spot height and the 10-m contour lines were digitized from topographic maps. Elevations between 0 and 10 m were derived from information on physiography (e.g., tidal flats and beaches). These are interpolated using a Triangulated Irregular Network (TIN). For fishponds and existing mangrove areas, information was extracted from 1989 Landsat TM data using MICROBRIAN and imported to SPANS as raster files.

Mangrove reforestation criteria are based on the guidelines set by the National Mangrove Committee of the Philippines and biogeographical studies on Philippine mangroves [Cadiz, 1987; Zamora 1989; TS-PNMC, 1986; Melana, 1987]. Table 2 gives a summary of the major parameters used in site selection for mangrove reforestation. In general, a buffer zone of 40-m wide mangrove forest should be maintained along river embankments and a 100-m belt facing for coastal protection (or a minimum of 20 m). Cutting of mangroves even in areas where there are fishponds is prohibited. Instead, fishpond lessees are required to plant or maintain mangrove trees within their jurisdiction. Those given permit to cut mangroves (e.g., commercial timber) are also required to conduct silvicultural activities. Recently, activities (e.g., agriculture, timber cutting) in public lands with mangrove forest and in forest reserve areas have been prohibited.

In determining the potential sites for brackishwater aquaculture, a series of thematic maps were overlayed based on the criteria in Table 1. Likewise, similar procedure was used for potential mangrove reforestation sites but based on Table 2. From the recommendations of the ICAMPLG, brackishwater aquaculture development should be geared towards intensification rather than expansion. At the same time, efforts should be directed to mangrove reforestation, especially along productive fry grounds, periphery of fishponds and certain coastlines. As such, a cross tabulation of the potential areas for brackishwater aquaculture and mangrove reforestation resulted in allocation of some areas in the former for reforestation purposes.

3. RESULTS AND DISCUSSION

Preliminary analysis using GIS showed an aggregate total potential brackishwater aquaculture areas of about 35,699 ha (Table 3; Fig. 2). The procedure used matches closely the site selection criteria. In a separate analysis, result showed that 66% (10,400 ha) of the total area for fishponds and mangroves fall within first 3 categories. About 22,252 ha met most of the criteria listed in Table 1. In terms of approximity to water sources, all areas categorized as excellent fall within 3 km from the seashore and rivers while for the good category, 65% and 57% fall within 3 km from the river and seashore, respectively.

In view of the recommendations of ICAMPLG regarding mangrove rehabilitation, some of the potential aquaculture areas have been earmarked for mangrove reforestation thereby reducing the overall extent of the former. Table 3 also shows the adjusted values.

Although there are a number of parameters that has been listed in Table 1, not all thematic maps were used. For example, the erosion and slope maps are not necessary if elevation map is available. At times, the use of erosion and slope maps can exaggerate areal extent of potential sites, especially if the slope is flat but elevation is above the ideal tidal range. One difficulty encountered is on the accuracy of the thematic maps. Since these are produced elsewhere (e.g., Bureau of Soils and Water Management) with insufficient background information, we attempted minor corrections where some "ground truth" information is available.

The aggregate total potential area for brackishwater aquaculture has been substantially reduced as a result of reallocation for mangrove reforestation. It is expected that this be further reduced once additional information, especially through field verification will be available. For example, spatial distribution of tourist resorts is not available. Some of the potential sites fall within tourist resorts but the areal extent is not known by this study. Another example is on the settlements. The topographic maps used are more than 10 years old and there has been considerable settlement expansion not to mention changes in the coastline due to the July 1990 earthquake. Thus, updated information through Landsat imagery and aerial photos will be needed in order to establish the actual aquaculture potential sites.

The brackishwater aquaculture practice, especially for milkfish in the Lingayen Gulf area, is largely traditional, characterized by low farm inputs (low stocking density, use of natural food, poor farm management) resulting in low yield (1,000 kg/ha as against 2,000 kg/ha elsewhere). Thus, for milkfish aquaculture, development should be geared towards intensification rather than expansion. In contrast, farm size for shrimp culture is generally small (<5 ha) but operated at a semi-intensive level (i.e., high stocking density with supplemental feeding and aeration).

How would the result of this study be useful in the context of brackishwater aquaculture development? Recently, ricelands and some agricultural lands have been converted to shrimp farming. This will clearly reduce the area for staple food production. The identification of potential sites, therefore, can discourage the conversion of agricultural lands to aquaculture, especially for shrimp culture.

Mangrove potential sites have an aggregate total of 19,515 ha of which 12,678 ha is suitable (Table 4; Fig. 3). The values are the result of the adjustment made on the brackishwater aquaculture potential sites mentioned earlier.

There are only 3 categories used in mangrove site selection based on Table 2. These are suitable (meet all criteria), less suitable (does not meet all criteria) and not suitable. The above result needs field verification to establish the actual potential areas similar to that for brackishwater aquaculture. Although the result is preliminary, the procedure used in this study has demonstrated that the areal extent for mangrove reforestation is wider than previously assumed, at nearly 20 times the ongoing projects. Even after field verification, the area may still be substantial.

The procedure used in this study is based on biogeographical parameters, mostly spatial while those used for ongoing projects lack such an approach (e.g., interviewing old folks whether an area was formerly with mangroves). The mangrove cover in Lingayen Gulf area is patchy. Based on the 1950s topographic maps, about 50% of the mangroves areas had been converted to fishponds for the past 40 years. This could mean that most of the mangroves had been logged prior to the Second World War.

Lingayen Gulf is a very productive fishing and fry grounds. The ecological importance of mangroves in fisheries provided the reason for conservation. The lack of proper technique in site selection, insufficiently trained staff and budgetary constraints have contributed to the slow implementation of mangrove reforestation projects. The standardization of site selection for mangrove reforestation using GIS can be a step towards accelerating the implementation of such projects.

4. CONCLUSION

The use of GIS in selecting sites for brackishwater aquaculture and mangrove reforestation has been demonstrated in this study. Ground truthing including verification of the accuracy of thematic imformation is necessary in order to standardize the procedure and provide statistically valid results. Minor attempt has been made in this study but it remains an important issue. It is expected that the 2-year GISCAMP project will resolve this and other issues such as updating of land use patterns, establishing a GIS databank on the coastal resources and zoning.

5. ACKNOWLEDGEMENTS

This study is part of the ASEAN/US Coastal Resources Management Project and funded by the United States Agency for International Development. The authors wish to acknowledge the assistance of the Ms. Angie Agulto, Ms. Zoriada Alojado, theRemote Sensing Center staff of the National Mapping and Resource Information Authority and the Bureau of Soils and Water Management. The authors also wish to acknowledge the sponsorship of the International Development Center of Canada to present this paper at the GIS conference.

REFERENCES:

Adisukresno, S. [1982]: Criteria for the selection of suitable sites for coastal fishfarms. South China Sea Fisheries Development and Coordinating Programme (SCS/GEN/82/42).

Cadiz, E. [1987]: Policies and regulations on Philippine mangroves. State of the art: mangrove research. PCARRD Forestry Research Series No. 4.

Hechanova, R.G. [1982]: Some notes on site selection for coastal fishfarms in Southeast Asia. South China Sea Fisheries Development and Coordinating Programme (SCS/GEN/82/42).

Khoo, C.K. and T.O. Wuan. [1982]: An integrated approach to the survey, investigation and study of coastal fishpond projects. South China Sea Fisheries Development and Coordinating Programme (SCS/GEN/82/42).

Melana, E.E. [1987]: Artificial regeneration of mangrove forests. State of the art: mangrove research. PCARRD Forestry Research Series No. 4.

Menasveta, P. [1982]: Environmental considerations for the development of coastal fishfarms in the Indo-Pacific region. Report of consultation/seminar on coastal fishpond engineering. South China Sea Fisheries Development and Coordinating Programme (SCS/GEN/82/42).

Poernomo, A. [1990]: Site selection for coastal shrimp ponds. Proceedings of the AQUATECH'90 conference, Technical and economic aspects of shrimp farming.

TC-PNMC [1986]: Country report - Philippines. Mangroves of Asia and the Pacific: status and management. Technical report of the UNDP/UNESCO research and training pilot programme on mangrove ecosystem in Asia and the Pacific.

Zamora, P.M. [1989]: Impact of fishpondification on the mangrove ecosystem of the Philippines. Symposium on mangrove management: its ecological and economic consideration. Biotrop Special Pub. No. 37.

Table 1. Criteria for brackishwater aquaculture potential sites.

Parameter	Criteria
Soil Type	Excellent to good soil types for brackishwater ponds are clay, clay loam and silty clay loam. Fairly good are sandy loam (at least 35% sandy), loam or silt with clay size fraction (<0.005 mm) content of at least 20%. Hydrosol (good category) has high clay content but is acidic. Ponds built with this soil type require liming and repeated flushing to neutralize acidity.
Physiography	Tidal flats are regularly exposed to tidal fluctuations, are excellent for siting fishponds. Beaches are good to fairly good depending on the soil type (at least <10% sand is good category). Alluvial landform can be fairly good provided it is within 5 km distance from the shoreline or 3 km distance from tidal rivers.
Slope	Coastal areas with 0-8% slope are generally suitable with 0-3% slope being excellent. Construction of ponds that rely on gravity for drainage or tides for water exchange should have slope between 0-3%. In terms of elevation, this is between 0 to 1.8 m from tidal datum (mean low water, MLW). For farms that will use pumps, slope up to 8% is still suitable provided elevation should not be more than 5 m from tidal datum.
Erosion and flooding	Areas with no to slight for erosion and flooding are suitable. The former is given the highest rating.
Land Use	Marginal areas within 5 km from the shore and coconut plantations rank high priority for conversion to aquaculture farms than agricultural areas. However, economic analysis is required to assess opportunity cost of conversion (not done in this study). Degraded mangrove lands (alienated) are also priority for conversion except in areas gazetted for mangrove reforestation. Buffer zone of mangroves should be maintained along riverbanks and seashore, however.
Settlements	Settlements, especially major ones should be demarcated. Ponds should be sited away from major settlements to minimize pollution from domestic wastes. No attempt to demarcate (i.e., actual boundary) settlements has been made in this study due to the unavailability of cadastral or settlement maps.
Roads	Suitable sites should be within 3 km from village or private roads and within 10 km from municipal or provincial roads. Delivery of farm products and supplies will incur some cost per unit distance from the road so that easy access to roads entails lower cost.
Fishponds	Existing fishponds should be excluded in the final analysis to determine the exact potential sites.
Buffers	Buffer zones along river banks, shorelines and roads are necessary as setback lines for fishpond development. About 50-m buffer is considered on both banks of rivers while 100-m buffer for the shoreline. These should be planted with mangroves as protection from wave action.

Table 2. Site selection criteria for mangrove reforestation.

Parameter	Criteria	Ranking	Remarks
Physiography	Tidal flats	1	Regularly flush by tides
	Beach ridges and lines	2	Occasionally inundated at high tides
Soil Type	Clayey, clay loam	1	Suitable for most mangrove species
	Silty clay loam	1	like *Rhizophora* and *Avicennia*
	Sandy	2	Suitable for many non-mangrove species like coconut, *Casuarina*
Settlements	> 150 m distance	1	Buffer zone around settlements
	≤ 150 m distance	2	
Accessibility:			
from national roads	< 5 km distance	2	The further away the site from the
	5 - 10 km distance	1	road, the better to minimize disturbance from ongoing economic activities
from shoreline and rivers	0 - 3 km distance	1	Sites should be located along the
	3 - 5 km distance	2	seashore and riverbanks as protection against wave action in addition to its ecological functions for coastal waters

1: suitable; 2: less suitable

Other parameters not directly used in the overlay procedure:

Existing mangrove areas	This is to quantify the areal extent of existing mangrove areas including its location and present status. Useful in determining what level of reforestation/conservation effort is needed.
Old mangrove areas and nipa swamps	This is useful in determining the past areal extent of mangroves. Unfortunately, most of the mangrove stands in Lingayen Gulf were logged prior to the Second World War (converted to fishponds). Nipa swamps are closely associated with mangroves but of more direct economic importance. Hence, this is usually conserved by the local people.
Existing fishponds and other land uses	Existing fishponds and agricultural areas are not suitable areas for mangrove reforestation projects. Agriculturally non-productive areas and marginal lands (built-up areas) along the shore and river banks affected by tides are generally suitable for medium - large-scale reforestation projects (> 10 ha). For fishponds, mangrove planting along the periphery of dikes is desirable to protect against wave action. This is patchy and narrow, however, and does not contribute very much to the overall productivity of the coastal waters.

Table 3. Potential areas for brackishwater aquaculture.

Rank	Area (km²)	Area (km²)[a]
Excellent	8.95	0.49
Good	209.04	26.88
Fairly Good	134.47	134.47
Not Suitable	1,440.89	1,440.89
Existing Fishponds	148.25	146.02
Existing Mangroves	9.50	9.50

a Adjusted for mangrove rehabilitation.

Rank	Approximity to Water Sources: River 0 - 1 km Distance (km²)	River 1 - 2 km Distance (km²)	Shore 0 - 3 km Distance (km²)
Excellent	5.29	2.05	8.95
Good	110.48	24.76	119.22
Fairly Good	20.21	11.45	115.27
Not Suitable	267.76	192.86	339.33
Fishponds	112.87	10.58	98.79
Mangroves	4.84	2.70	1.40

Table 4.Potential Mangrove Rehabilitation Areas (Adjusted)

Rank	Area (km²)
Suitable	126.78
Less suitable	68.37
Fishpond areas	146.02
Existing mangrove areas	9.50
Ongoing mangrove projects	6.74

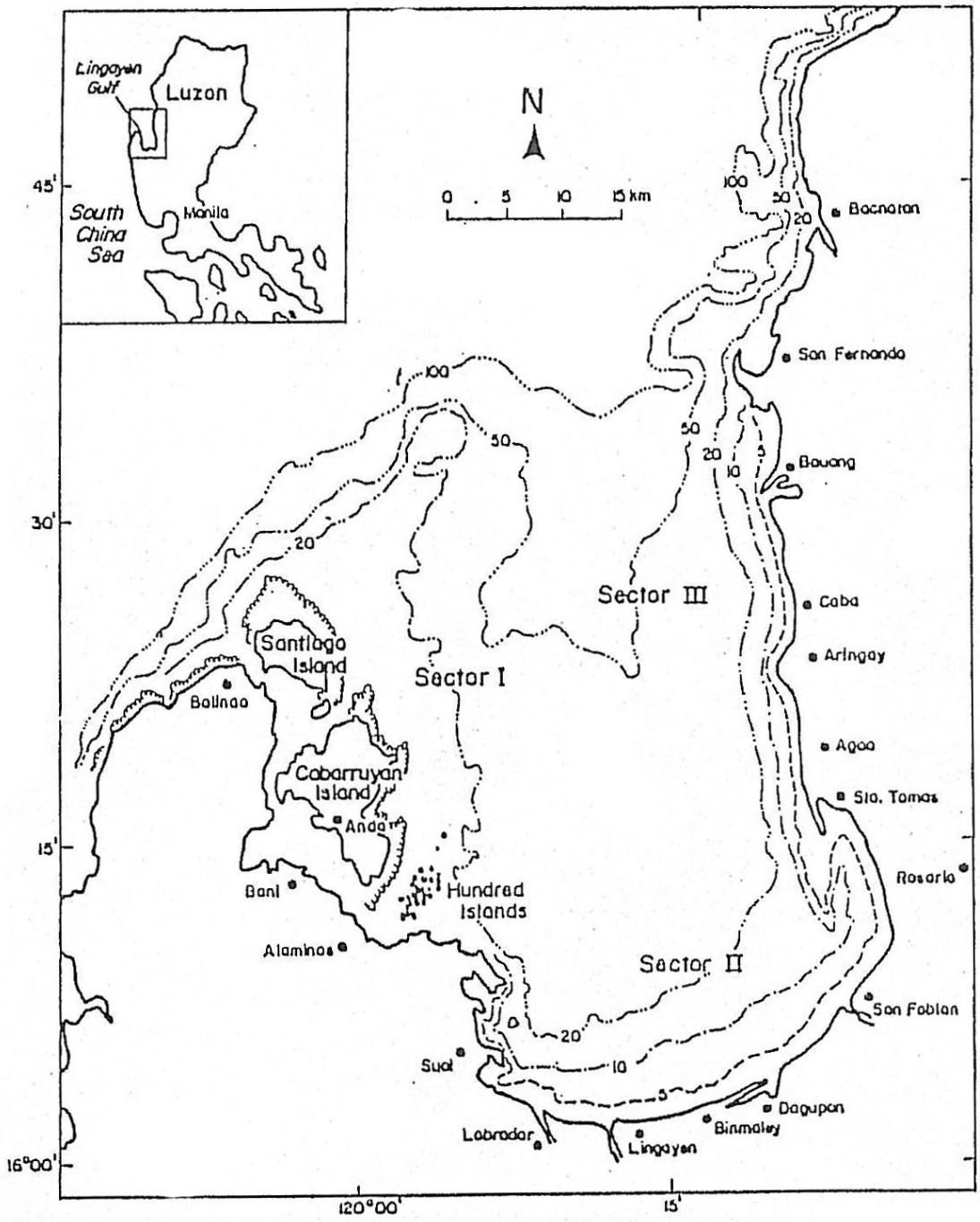
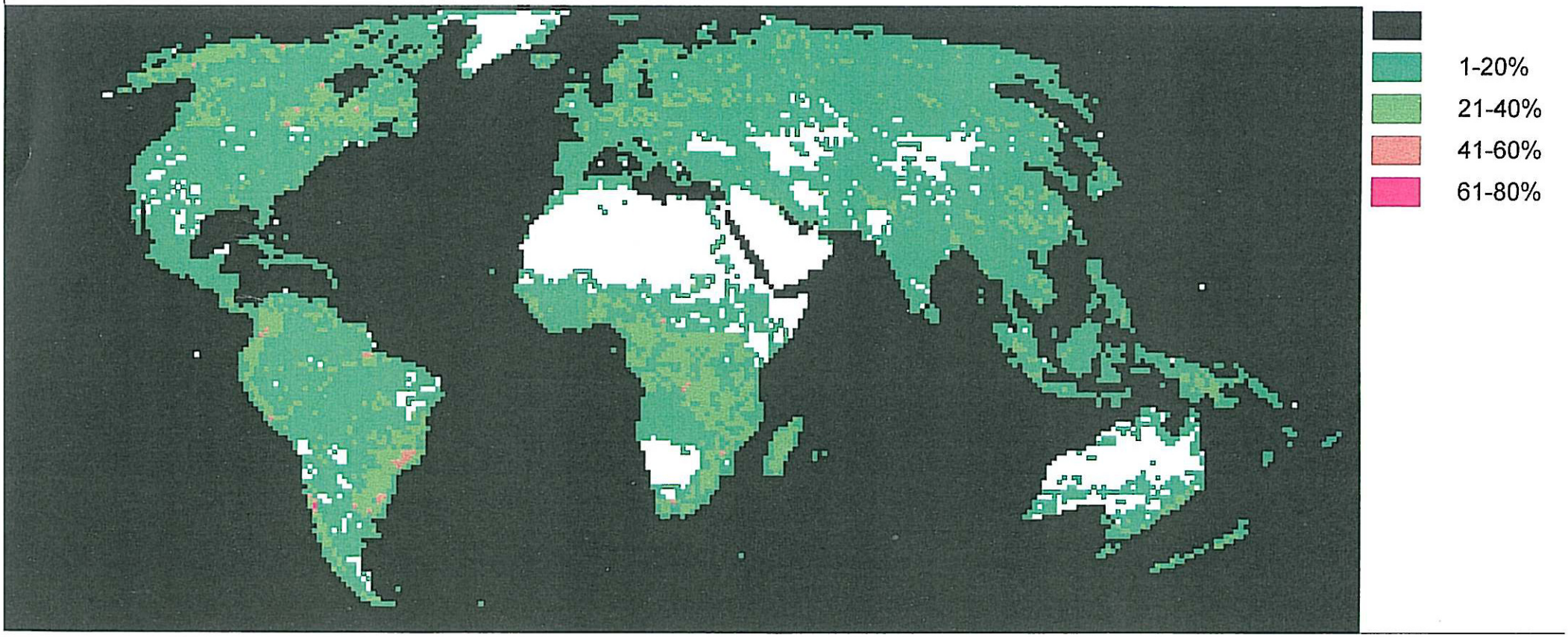


Fig. 1 The Lingayen Gulf, Northwestern Luzon, Philippines.

Figure 7. Frequency of Perennial Rivers (Counts/Grid Cell)



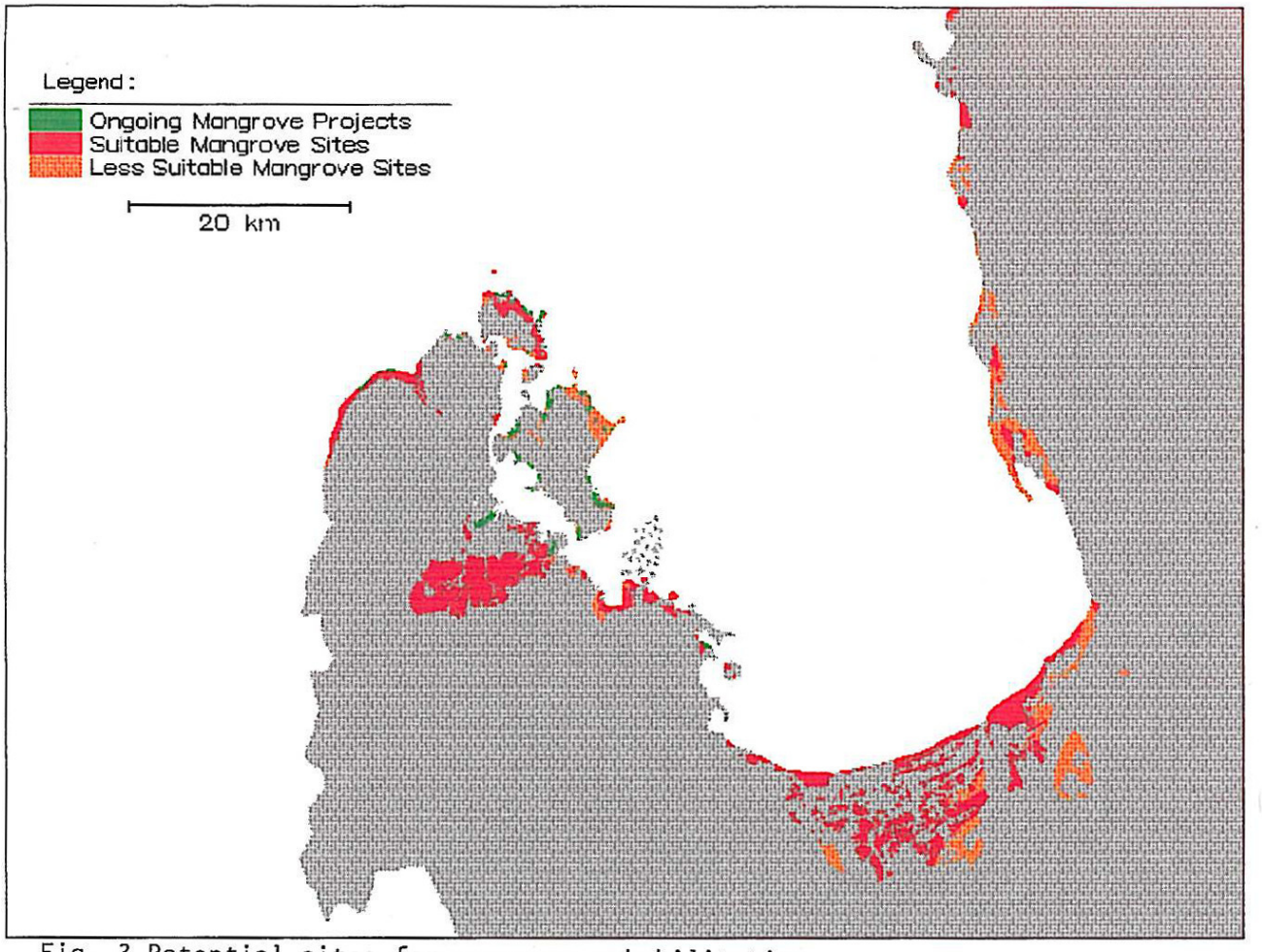


Fig. 3 Potential sites for mangrove rehabilitation.