P20

# HIGH RESOLUTION SATELLITE DATA FOR ASSESSMENT OF TROPICAL COASTAL FISHERIES. CASE STUDY IN THE PHILIPPINES

# DONNEES DE TELEDETECTION DE HAUTE RESOLUTION POUR L'EVALUATION DES PECHERIES COTIERES TROPICALES. L'EXEMPLE DES PHILIPPINES

**J. POPULUS (1), D. LANTIERI (2)**

*(1) IFREMER Centre de Brest - BP 70 - 29280 Plouzané FRANCE.*
*(2) FAO Remote Sensing Centre - Via delle Terme di Caracalla - 0100 Rome ITALY.*

**ABSTRACT**

*The Philippines Fisheries Sector program, F.S.P. with loan assistance from the Asian Development Bank, is now being implemented. The FAO Remote Sensing Centre assessed the possibilities of new mapping techniques emerging form high-resolution satellite data for such a program. Generally, there is a crucial lack of baseline information about the physiographic environment, which makes it difficult to assess resources and start efficient management. This pilot study shows how much information could be obtained from digitally processing SPOT images over the first F.S.P. test site in Calauag, Quezon Province. It describes the methodologies and makes recommendations on several points : proper image acquisition, guidelines for efficient and through field survey (an essential phase), digital and visual analysis techniques and also organizational issues to produce timely documents. Costs are examined from an operational point of view, on the assumption that studies will be reproduced on several sites around the country.*

## RESUME

*Dans le cadre du Fisheries Sector Program (F.S.P.) actuellement mis en oeuvre aux Philippines sous l'égide de la Banque Asiatique de Développement, le Centre de Télédétection de la F.A.O. à Rome a l'intention de démontrer l'intérêt des nouvelles méthodes de cartographie apportées par les images de satellite à haute résolution. En général, quand on lance des programmes d'inventaire des ressources ou de gestion du littoral, on se heurte d'emblée à un vide d'information et de documents de base. Sur le premier des sites du F.S.P., à savoir la région de Calauag, Province de Quezon, l'étude pilote montre quel type d'information peut être facilement extrait d'images SPOT. La méthodologie est décrite et quelques recommendations sont données : comment acquérir une bonne image, comment effectuer la mission de terrain de manière efficace, comment organiser le déroulement des documents de qualité. Les coûts sont examinés, non pour cette étude pilote elle-même mais en se plaçant dans l'hypothèse d'une couverture complète des sites du F.S.P.*


## GENERAL FEATURES OF COASTAL MANAGEMENT IN THE PHILIPPINES

Economic activities in the coastal area have direct or indirect impacts on coastal resources relating to the level of exploitation, impact of degradation and the sustainability of the resources to continuous exploitation. These activities also have direct bearing on coastal development. Major coastal activities in tropical countries which are relevant to coastal resources are fishing, aquaculture, waste discharge, mining, oil drilling, mangrove logging. Upland activities also dramatically affect coastal environments, such as deforestration, agricultural practises, mining. Unisectorial activities brought about economic interest have resulted in serious resources use conflicts in many nations. Colour fig. P20A.

The aim of management is to ensure wise use of resources on a sustainable basis and to minimize conflicts in resource use through a set of management options.

Usually, statistics on the state of natural resources are widely regarded as untrustworthy or out of date and some statistics are simply not collected. This justifies the use of remote sensing, which, unlike any other traditional method, can rapidly provide a snapshot of land uses over large areas in a cost effective way.

The most prominent geographic fact of the Philippines is that it consists of 7,107 islands with a total coastline of 17,460km. About 55 % of the population resides in some 10 000 coastal barangays, plus larger urban centers. Associated land use activities concentrated on the coast are transportation infrastructure, industrial and commercial development, lowland agriculture (especially rice and coconut), aquaculture, tourism and recreation, land reclamation and waste disposal.

Coastal and near-shore fisheries are a public resource, the open-access nature of which has attracted the most impoverished elements from adjacent agricultural and coastal areas and induced them to use non-sustainable extraction techniques. Most of this population is dependent on the near-shore (municipal) fisheries, which are extremely sensitive to two habitats which figure in different parts of the life cycles of various fish, namely the coral reefs and the mangrove forests. The accelerated cutting for fuelwood and conversion of mangrove areas to brackish water fishponds have reduced the 450 000ha of the mangroves thought to exist in 1918 to 240 000ha in 1980 and 15 000ha today. Coral reefs have been destroyed by the cutting and export of coral and severely damaged by certain fishing techniques. Only 30 per cent of the remaining reefs are considered to be in good to excellent condition. Near-shore habitats are also ecologically linked with the inland and upland areas : increased water turbidity and reduced light penetration due to soil erosion reduces growth, or even kills through smothering, the off-shore coral reefs and seaweeds beds. Destruction of coastal mangrove forests opens interior areas to increased typhoon damage, creating a backwards linkage.

## THE FISHERIES SECTOR PROGRAM (F.S.P.)

To address the major concerns of the sector, the Department of Agriculture, with the assistance of the Asian Development Bank, has formulated the Fisheries Development Program for 1990-1994.

The objectives of the program focus on specific sectoral priorities, as follow : On Coastal Fisheries, the program will address a) regeneration, conservation and sustained management of aquatic resources with emphasis on balancing fishing effort to maximum sustainable yield ; b) rehabilitation and protection of the coastal environment, and c) alleviation of poverty among municipal fishermen particularly diversification of their sources of livelihood.

## OBJECTIVES OF THE PILOT STUDY

The objectives of this pilot study are the following :

a) Provide a reliable and up-to-date coastline interpreted from the satelite image, which can be used for baseline maps, as a support for statistics and other data to be mapped for the F.S.P.

b) Give a reliable description of the intertidal space which is basically occupied by mangrove, non vegetated wetlands and aquaculture ponds.

c) Assess the condition of shallow waters which are of primary relevance to municipal fishing.

d) Get an idea of the bathymetry, which obviously can be used for navigation but also could be used for such developments as artificial reefs, sea-weed culture or the like.

e) Evaluate land use and land condition and its influence to the coastal area (erosion for instance). Possibilities of either processing the land area itself or merging external information will be examined.

## STUDY AREA AND DATA USED

### Study area

Quezon province is situated in climatic region II, an area with no dry season with a very pronounced maximum rain period from November to January. The eastern coast is sheltered neither from the northeast monsoon and the trade winds nor from cyclonic storms. (Colour fig. P20A).

The general oceanographic features of Lamon bay are the following :

a) In the winter, from January to may, the water temperature is around 25°C, with occasional low cells down to 23°C offshore in the Pacific. Prevailing winds are north-easterly and easterly, hence inducing wind-sea and swell from the same direction. Swell heights decrease from an average 2 meters in January to 1 meter in May.

b) In the summer easterly and north-easterly wind persist in Eastern Luzon. The water temperature reaches a fairly steady 29°C temperature all along the East Luzon coast.

The tides are of semi-diurnal type with small inequality. The principal variations follow the moon's changing phases. The tidal amplitude in Lamon bay may reach 1.5 meters on springs tides.

Lopez bay and Calauag bay (colour fig. P20A) are separated by a peninsula densely covered with coconut trees, which is ended by Roma point. The 0.5 mile wide Silangan pass between Roma point and Silanga point on Alabat island is fringed by coral reefs : its actual width proper for navigation is only 500 meters and its depth quite irregular. Most of Lopez bay is more than 18 meters deep and Hondagua Harbor can take ships with 9 meters draft. Most of Calauag bay is clean of any danger except of its north-eastern shore where the reef fringe is wider. Sedimentation occurs in both bays : the far end of Calauag bay is heavily covered with mud flats resulting from the Calauag river siltation. High turbidity can be observed at all times. In Lopez bay, only the southern most past is occupied by mud flats generated by the very small Lopez river. Even in the dry season, sediments are removed by wind and small waves, producing turbid water.

## Data used

### *Spot imagery*

The Spot Image Company's archive was consulted for grid number 306322 covering Lopez and Calauag bays. After examination of the quick-looks of the 16 scenes acquired by Spot Image, the February 5, 1988 image, although with cloud label "1" (below 50 % cloud cover) turned out to be appropriate for a coastal study, since the clouds only cover the uplands.

The XS image (multispectral mode, 20 meters resolution) was pre-processed by Spot Image to level 2A in the Universal Transvere Mercator cartographic projection, currently used by the NAMRIA topographic survey. This means that accurate registration can be obtained by mere adjustment of the scale factor. Colour fig. P20A shows a classical false colour composite of the study area. High turbidity can be seen in Calauag bay and the South eastern cove of Lopez bay.

### *Ancillary data*

There is very little bibliography concerning the Quezon province in general, let alone its coastal geomorphology. The only information readily available can be found in the Nautical Instructions.

As regards maps, the National Mapping Authority (NAMRIA) can provide a complete coverage of the whole country at scales 1/250 000 and 1/50 000. Unfortunately, the sheets are mostly out of print or non available, except on louzy black and white paper. Two nautical charts could be found on the area, one at scale 1/200 000 covering the whole of Lamon bay and a detailed one, at scale 1/20 000, mainly designed for approaches to Hondagua Harbor and Silangua pass.

Land use maps at scale 1/250 000 derive from Spot colour composite analysis can be found at NAMRIA (colour fig. P20B). They provide useful information about the upland vegetation and land cover. In the coastal zone, fishponds reclaimed from mangrove are distinguished from other fishponds. Their total surface seems reliable, whereas the coral reef estimates look notably incomplete.

Could also be consulted in this particular area : a) a "Fishery Ordinance Map" of the municipality of Calauag showing the barangays limits within the munipality (scale 1/50 000),

b) the "Calauag Mangrove Forest Reforestration Project Map" with cadastral parcels for project implementation.

No aerial photos could be found available.

## FIELD SURVEY

The general purpose of a field survey is to investigate a given area or type of environment in order to ensure reliable image interpretation and processing. It allows the interpret to gain knowledge regarding the way reality is expressed through remote sensing.

Six days were actually spent in the Calauag area from March 3 to March 10, 1990, with the support of three F.S.P. scientists. A fishermen boat was kindly put at our disposal. This boat was used for a four day exploration of the area, which consisted mainly in sailing along transit lines defined by conspicuous landward marks. The transects were positioned by using properly enhanced hard copies, keeping in mind that they should exhibit large homogeneous facies. One day was used for water transparency determination. A Cimel radiometer had been carried therefore. This measurement requires a large area with constant bottom type composition and varying depth, which is quite tricky to achieve. (Indeed, when Depth increases, bottom type tends to change).

Some depth soundings were also made with a very simple sounding line. Positioning at sea was performed using available landmarks and a simple hand-compass. As a matter of fact, very few conspicious marks are available, except for Hondagua Harbor, a couple of islands off the northern coast of Lopez bay and the outer slopes of Roma point and Alabat island. The general background is a rolling terrain covered wtih coconut trees. Even coastal villages are often hidden from a seaward position.

Land survey was limited to investigations in both aquaculture areas of Calauag and Lopez. In Lopez, we followed the railway line which actually goes accros the intertidal area most of the time. Natural and reforestration mangrove sites were visited on the North eastern side of Calauag bay as well as along the Alabat island shore and observations put down.

### <u>The Image Processing</u>

*Intertidal zone processing*

The main features to be identified in the intertidal zone are mangrove forest and aquaculture ponds.

Firstly, a vegetation index defined as XS3/XS2 was applied to discriminate three main classes characterized by the vegetation density.

- High index values are roughly representative of high vegetation density. a) either thick stands of mangrove trees, b) or patches of dense grass around aquaculture areas. As a matter of fact, the interpreter has to use his knowledge of the environment to separate between the two.

- Rather the same way, the low density class may represent young mangrove stands (mainly on the seaward fringe) or, when located in aquaculture areas, sparse vegetation covering empty ponds.

- Bare soil class (index values lower than 42) can in its turn be further described by its moisture which is done by thresholding its infrared channel. Two classes come out a) high moisture (XS3 lower than 32) means watered ponds in activity b) low moisture is found in ponds temporarily idle.

*Shallow water processing*

The methodology to be used for mapping underwater features depends on several factors, i.e. a) water transparency, b) general bottom physiography c) abundancy of field data. Generally in the Philippines, good water transparency can be expected, namely around 15 meters of visibility. Of course, turbidity may locally affect water transparency as it is the case in Calauag bay an partially in Lopez bay.

Shallow water facies usually consist of coral reefs, sandy shoals, sea grass and seaweed beds. Several papers illustrate the diffculty of mapping underwater features, due to the interference of bottom type and depth when writing the physical equations. Classifications are rather ineffective since grey levels on XS1 and XS2 are not sufficient to solve for bottom type and depth (and again, it is even more difficult to define training areas at sea than on land).

For a given bottom reflectance, (Lyzenga, 1983) showed that when plotting log ($XS1-XS2_\infty$) versus log ($XS2-XS2_\infty$), the points tend to scatter along a line with slope K1/L2 ($XS1_\infty$ and $XS2_\infty$ being the values for deep water and K1 and K2 the water attenuation coefficients in bands XS1 and XS2). Changing the bottom reflectance will induce a displacement of the line's origin ordinate, still with the same slope. Hence, an original index referred to as the Bottom Type Index was established (Engel, 1988).

$$Y = K2 \mathrm{Log}\,(XS1-XS1_\infty) - K1 \mathrm{Log}(XS2-XS2_\infty)$$

K1 and K2 were determined in the field by radiometric measurements. The slopes of the regression lines are respectively K1 = 0,065 and K2 = 0,21, which means that maximum depth of light penetration is 3,5 meters for XS2 and 13,9 meters for XS1. These values are assumed to be fairly constant in time.

The index is applied to the whole shallow water area : when XS2 decreases to reach its constant deep water value, K1 Log XS2 stays very small and Y becomes equivalent to K2 Log XS1 with no more influence from XS2.

As for depth computation, it can then theoretically be performed independently in each class. To be of some relevance, this operation would require quite a number of ground control points, which is rather unfeasible here as mentioned above. At any rate, it seems that depth can only be worked out with some confidence in simple environments such as uniform sandy lagoons and the like (Le Visage, 1989).

### Validation

The problem induced by lacks of logistics and inherent natural complexity were reported above. Validation as such was not performed and no figures such as confusion matrixes could be issued. A few transects at sea were used to label the classes devided from image processing. Land investigation of the intertidal zone permitted general checks at ground level. In one case (Calauag pond area), photographs were taken from a steep hill about 100 feet high. Unfortunately the state of the ponds in march 1990 may be rather different to that of 1988, making it difficult to use the photos for validation.

## RESULTS - DISCUSSION

### The Intertidal Zone (see color fig. P20C)

The intertidal zone was divided into four classes, namely : dense vegetation in red, sparse vegetation in pink, dry bare soil in light yellow and water surfaces in dark grey. Surface areas for each class shown in Table 1. The intertidal zone spreads on 1970 ha, divided into 930 ha of vegetation and 1 040 ha of bare soil. Dense vegetation represents 190 ha, an amount accounted for mostly by the northern shore of Calauag bay. However, most mangrove is only secondary growth for an area of 740 ha.

Tidal areas can also be divided by the interpreter into natural and man-managed. The latter are found both in Calauag and Lopez. Table 1 shows that whereas ponds occupy 480 hectares within these two main aquaculture areas, 270 hectares of intertidal water spreads in the remaining tidal areas. Such low and very moist tidal flats are of little interest for potential aquaculture development.

Conversely, dry soils spread on 230ha in aquaculutre areas and only 60 hectares our of them. This tends to prove thas most ponds must have been built on former mangrove flats. It is difficult to say whether these 230 ha of dry soil ponds are left idle or just temporarily dried out. However, a quick check in the field should confirm that only a small fraction of operative ponds could be dry at the same time, implying that most of the 230 hectares are in fact idle ponds.

As far as mangrove is concerned, it is well known that most primary stands have been exploited. The north-eastern shoreline of the map is fringed by a strip of tidal flats mostly occupied by low-lying mangrove trees. Their low density allows quite a high proportion of moist sediment (or water at high tide) to be seen from above thereby accounting for low vegetation index. When higher trees are still present, the foliage cover is much higher, and the index too. It seems that a vegetation index can be used with confidence within the mangrove stratum. In case other main types of vegetation are to be found (e.g. tidal grass), a previous segmentation has to be performed by means of usual classifications based on prior recognition in the field. Over the previously-defined aquaculture areas, very little high density vegetation appears (just a couple of coconut trees groves). Light pink represents mixtures of grass and shrubs around or inside derelict ponds.

The Shallow waters (see colour fig. P20C)

Shallow waters are divided into five classes, namely a) two classes for sea-grass beds ( two shades of green), either dense or not, usually found at depth less than one meter, b) one class for sandy bottom (yellow), with depths between 1 meter and 4 meters, c) two classes for constructed bottom (light and deep magenta) which are labelled coral 1 and 2 in table 1 below. Surface areas are also computed, after turbid patches have been discarded.

It should be assessed whether the two coral classes do represent different states of the coral or whether the water depth is involved. The field trip investigation tends to be in favour of the second hypothesis, since live coral and damaged coral do not seem to look different enough to be differentiated. However, this topic needs further work, especially radiometric measurements on large homogeneous patches. The two green classes may also deserve a closer look as to sea-grass density. The sea-grass beds might be worth monitoring for ecological purposes.

Radiometric measurements should mainly be performed over homogeneous coral patches, trying to vary depth, thereby getting an idea of extinction depths for XS1 and XS2 over coral bottom. It is anticipated that these values should be around 10 and 3 meters respectively. This means that the two pseudo depth lines respectively vary in ranges 10/13.9 and 3/3,5 meters. To put it the safe way, only lower values (i.e. 10 and 3 meters) are considered and labeled on the final map (colour fig. P20C).

## COST ANALYSIS

It is actually quite awkward to attempt a cost-benefit analysis of a maping or remote sensing project as the objective is to compare a previous situation when people managed with what information they had, (i.e. non-thematic maps and some statistics they had be happy with it) to nowadays situation with emerging tools allowing genuine thematic mapping.

In this study the economic analysis was limited to a cost benefit comparison between two methods to map coastal features : with satellite data and with aerial photos.

### Cost using satellite remote sensing

In an attempt to evaluate operational cost, let us suppose we have to deal with the 12 bays of the F.S.P. project. As shown in this study, three 20km square sub-images per Spot scence will generaly be sufficient to cover the area of interes. Therefore, 36 maps have to be produced.

Production costs are estimated around 260 000 USD. As 36 maps represent 16 000km$^2$, the results per km$^2$ cost just around 17 USD. This high cost is explained mostly by the fees of an external remote sensing expert but also to some extent by the degree of interactivity required in a) the image processing methodology (coastline, use of indexes not as automatic as classifications) b) the time consuming operation of overlaying complementary information which is needed to produce a rather complete thematic map. If we suppose the job can be handled in the future by a Philippine expert, probably the cost can be brought down to come 13 USD. It should be emphasized that such unit costs should not be compared to those obtained for agricutlure or forestry for instance. Probably, rather than per square kilometer, costs should be established per linear kilometer of coastline.

### Costs using aerial photography

If such a study had to be carried out with traditional means, vertical aerial photography would have to be used (since oblique photos do not allow more than rough qualitative aerial estimates). Existing aerial photographs will generally be of little use, since a) they are often out of date, especially when investigating rather recent land use changes b) black and white is not very good at bottom type mapping.

The cost of a black and white coverage of the 12 F.S.P. bays can be estimated around 150 000 USD. High flight altitude will be preferred in order to decrease the number of photos and make splicing easier, yet this will imply more stand-by time because of more severe cloud problem. Specular reflection on the sea surface will have to be carefully avoided.

Photo-interpretation can be performed either on a cartographic workstation including a digitizing table or manually or transparencies, as was the case in the SSC land use mapping. The transparencies then had to be scanned and each polygon labelled before going into the database. The total worktime for map production is likely to be of the same order as that required by the remote sensing method, however calculation costs will be reduced. at the same time, a much less sophisticated workstation is required, since no image processing functions are required.

As for field survey, the figures will not be significantly reduced even though low altitude oblique photos can be obtained at the same time as the vertical mission.

Table 2 compares global figures for both cases. Aerial photography costs are those currently charged by private companies for orthophotos. The figures for map production are those anticipated by the authors, since no unit costs are easily available for such thematic mapping. (The time necessary to process the photographic coverage was taken equal to that of image processing whereas computational costs were reduced by a factor two.)

The costs turns out to be about 50 % higher with aerial photography that with Spot data. It shoud also be noted that the expectable results are not quite the same. In particular, aerial photography does not have spectral bands like the data and identification of such features as soil moisture or vegetation type will not be as effective. Even more so, little can be expected from black and white aerial photography for underwater features mapping. From the geometric point of view, Spot images do have a very high quality, which means that when the right planimetric identification procedures have been set up, the digital nature of the data ensures highly consistent results from one region to the other.

## CONCLUSIONS AND RECOMMENDATIONS

### Meeting the objectives

The final results of the map consist in a thematic map, color fig. P20C, together with some surfacial data contained in tables 1 and 2, this map provides a nice alternative to the regular topographic map which was based on an aerial photography mission dated 1951. It shows :

a) A reliable 1/50 000 scale up to date coastline to be used for baseline map for the F.S.P.

b) A reliable description of the intertidal space and particularly both local active and idle aquacutlure ponds, mangrove regrowth (degraded mangrove) ;

c) The condition of shallow waters, (up to 10 meters deep) where the bottom covered by sand, grass or coral could be localised. Some hypothesis (to be still verified were also made on the discrimination between sparse and dense grass and between live and damaged coral ;

d) Get an idea of the bathymetry : two lines showing respectively areas between 3 to 3.5 meters and 10 to 13.9 meters could be drawn on the 1/50 000.

## Recommendations

This experiment in the Philippines led us to formulate a few recommendations for subsequent similar operations.

### *Data Acquisition*

It was shown that although a great number of scenes with variable quality exist in the Spot image archive, none of them was perfectly suitable for the study. In order to avoid this, it should be advisable to program the satellite for high acquisition rate during the dry season.

### *Relevance of digital data*

First of all, the importance of using digital data should be especially emphasized here. When it comes to low radiometric values, which are found mainly over water as well as tidal areas, a specific digital enhancement (contrast stretch) should be applied in order to really search otherwise hidden features.

### *Atmospheric Correction*

In a first step, it is advisable to perform atmospheric and environment corrections a) for the sake of more reliable interpretation and in case field radiometric measurements are to be used jointly b) for the sake of potential comparisons which might be a value in the future. However, this step will be realistic only when a user friendly software has been written and made easy to transfer. In the meantime, corrections will have to be skipped and excellent image quality ensured as much as possile at delivery by Spot Image.

### *Field Trip*

First of all, this field trip was organized too early after the Spot products delivery, which did not allow for sufficient data processing prior to going to the field. Indeed, ideally two fields trips would be much better, because many questions still arise after the first one.

Secondly, logistics are fundamental. Aerial photography should be made available as much as possible. Aerial photographs is in all cases very helpful, as it allows to position homogeneous ground features at large scale. The field boat should be a rather quick one (minimum 10 knots so as to cover large stretches) and easy to manoeuvre, with little above water height in order to allow frequent snorkelling and overboard bottom scrutiny. It should have enough available space for setting up such devices as radiometers. Settings should be provisioned for portable echo-sounder and speedmeter. Big inflatable dinghies meet most of these requirements.

Thirdly, in rapidly changing environments, it is important that the field survey be (almost) simultaneous with image acquisition. Dedicated satellite programmation request, though it might take some time before a cloud-free image comes up, will better serve the purpose.

## REFERENCES

**CHUA THIA ENG, J. N. PAW**, 1987. Aquaculture development and coastal zone management in southeast Asia : conflicts and complementary. *Fifth symposium on Coastal and Ocean Management,* may 26-29, 1987, Seattle, Washington, USA).

**SAMSON E.D.**, 1985. Fisheries, p. 101-154 in G. Kent and M.J. Valencia (des.) Marine policy in Southeast Asia. *University of California Press, California.*

**THE WORLD BANK**, 1989. Philippines. *Environment and Natural Resource management Study.*

**TANRE D., C. DEROO, P. DUHAUT, M. HERMMAN, J.J. MORCRETTE, J. PERBOS, P.Y. DESCHAMPS**, 1986. *Logiciel 5S Simulation of the Satellite Signal in the Solar spectrum.* rev. 07/1987.

**AUZEL P.L.**, 1989. Calibration et corrections atmosphériques des images du satellite Spot. *Application aux études multidates. Mémoire de fin d'études. Mastère Spécialisé OCEAN. IFREMER DRO/AT.*

**LYZENGA D.R.**, 1983. Remote sensing of bottom reflectance and water attenuation parameters in shallow water aircraft and Landsat data. *Int. J. Remote Sensing, Vol. 2,* pp 77-82.

**ENGEL P.**, 1988. Heron Island. Great Barrier Reef, Australia. Etude thématique du récif par image Spot. *Mémoire de DESS de Télédétection,* Toulouse.

**LANTIERI D.**, 1987. Application des données SPOT pour les ressources renouvelables aux Maldives. *Colloque Spot 1. Utilisation des images, bilan résultats. Paris,* novembre 1987. pp 1151-1159.

**LE VISAGE Ch.**, 1989. Applications de la télédétection à l'hydrographie - spatiocarte marine -. *Bul. S.F.P.T. N 117 (1990-1),* pp 34-38.

**LOUBERSAC L., O. LEMAIRE, H. VARET, F. CHENON, P.Y. BURBAN,** 1989. Nature des fonds de bathymétrie du lagon et de l'atoll d'Aitutaki (Iles Cook) d'après des données Spot 1. *Photo Interprétation 89 5/6, Fasc. 4,* pp. 29-40.

**LOUBERSAC L., A. GROTTE, J. POPULUS, G. BELBEOCH,** 1989. Aménagement littoral et inventaire des potentialités aquacoles par traitement d'images Spot en Nouvelle Calédonie (ALIAS). Ministère des Département et Territoires d'Outre-Mer. *Rapport de convention FIDES 87/2/465005/F.*

**LOUBERSAC L., J. POPULUS,** 1986. The applications of high resolution satellite data for coastal management and planning in a Pacific coral island. *Geocarto International, Vol. 2,* 1986.

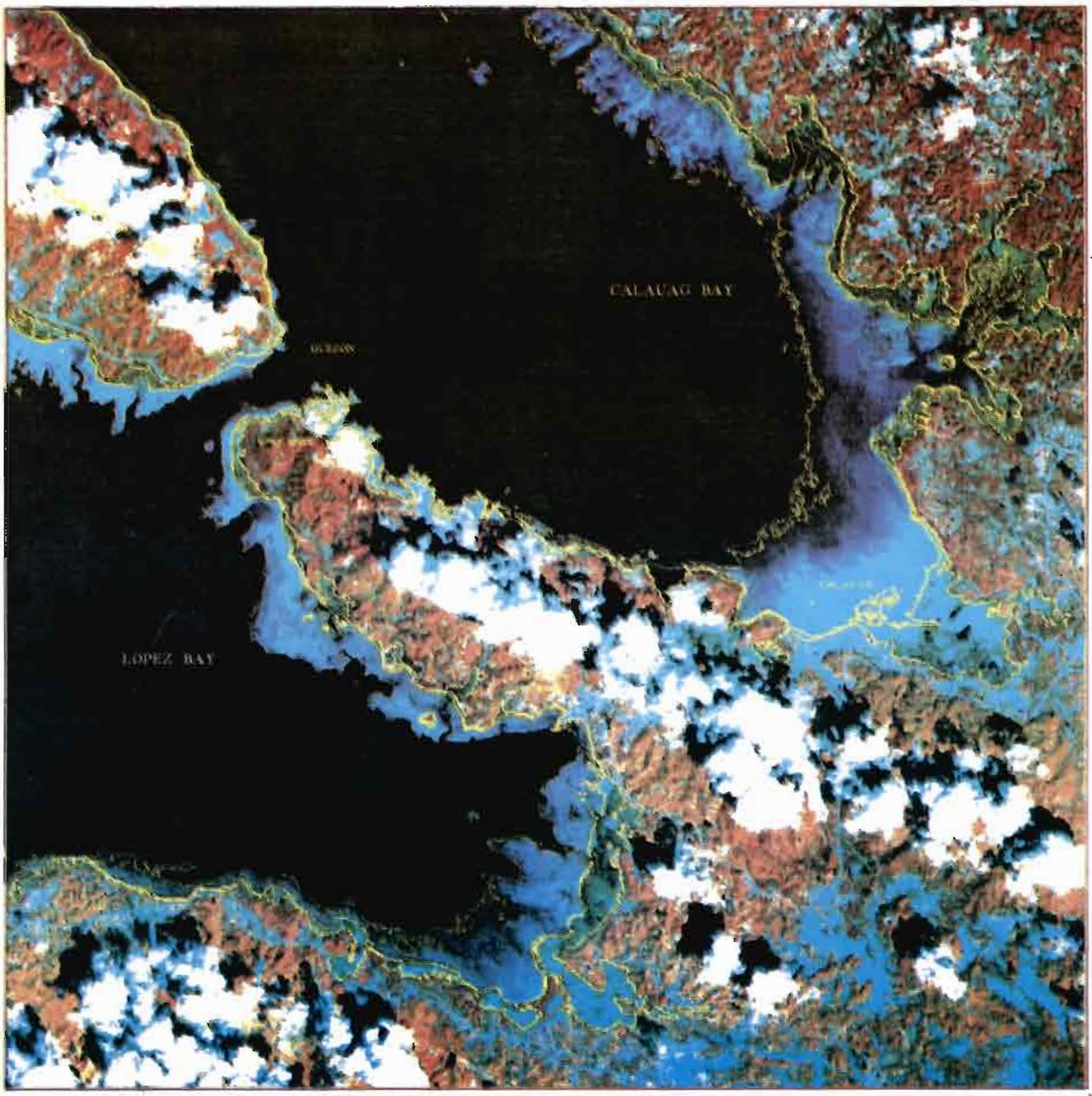
Table 1 : Class area for intertidal zone and shallow waters (hectares)

<table>
<tr><td colspan="2">Intertidal water</td><td colspan="2">Dry Bare Soil</td><td>Low Density vegetation</td><td colspan="2">High density vegetation</td></tr>
<tr><td>Ponds<br>480</td><td>Other<br>270</td><td>Ponds<br>230</td><td>Other<br>60</td><td>740</td><td colspan="2">190</td></tr>
<tr><td colspan="2">Dense grass beds</td><td colspan="2">Sparse grass</td><td>Sandy</td><td>Coral 1</td><td>Coral 2</td></tr>
<tr><td colspan="2">250</td><td colspan="2">520</td><td>1 800</td><td>1 650</td><td>170</td></tr>
</table>

Table 2 : Costs induced for mapping 16 000km2 of coastland (USD)

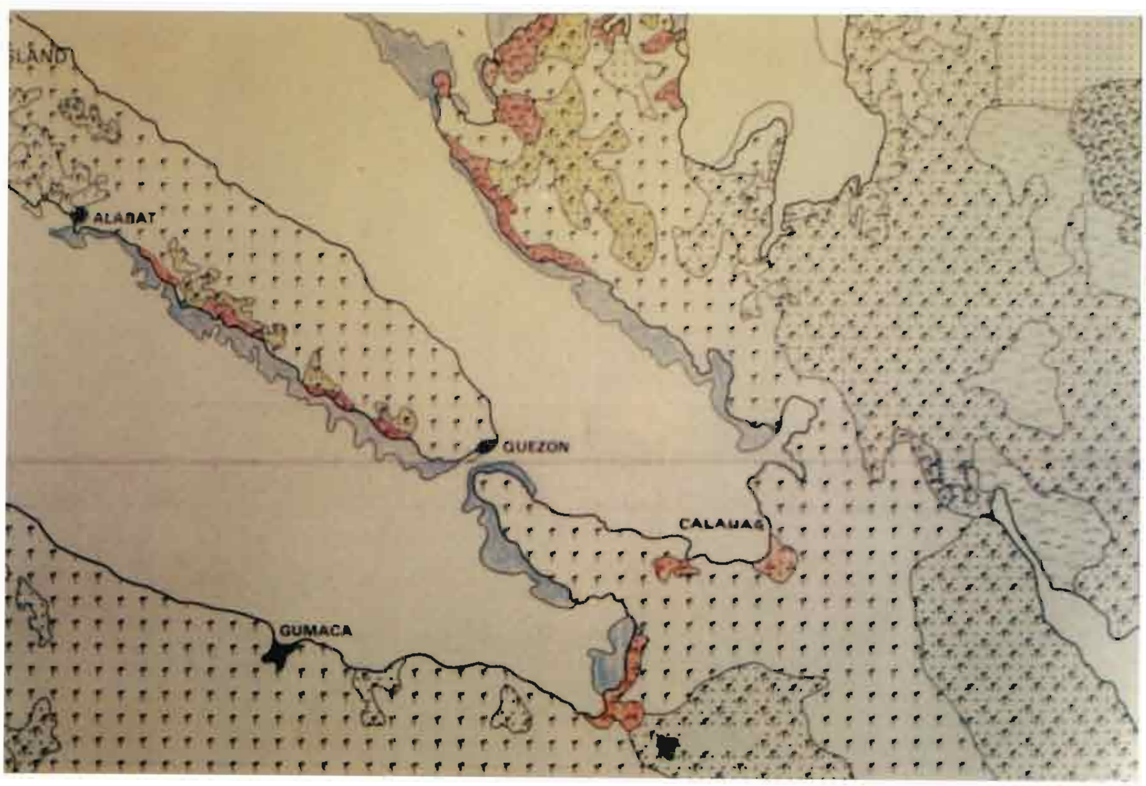
| | SPOT | Aerial photography (B. and W) | Aerial photography (Colour) |
|---|---|---|---|
| Data | 40 000 | 150 000 | 200 000 |
| Field survey | 40 000 | 20 000 | 20 000 |
| Map production | 133 000 | 103 000 | 103 000 |
| TOTAL | 213 000 | 273 000 | 323 000 |

P20A




P20A : 20x20km$^2$ area showing Lopez and Calavag bays, Quezon Province. SPOT false colour composite, feb. 5, 1988.
C CNES 88/dist SPOT IMAGE.

P20




P20B : 1/25 000 land use map of Lamon Bay and surroundings showing shallow waters in blue, mangrove in purple and aquaculture areas in red. Produced from SPOT images by the Swedish Space Corporation (SSC).

**P20**


P20C : Final document at scale 1/50 000 with emphasis on intertidal and shallow water zones.

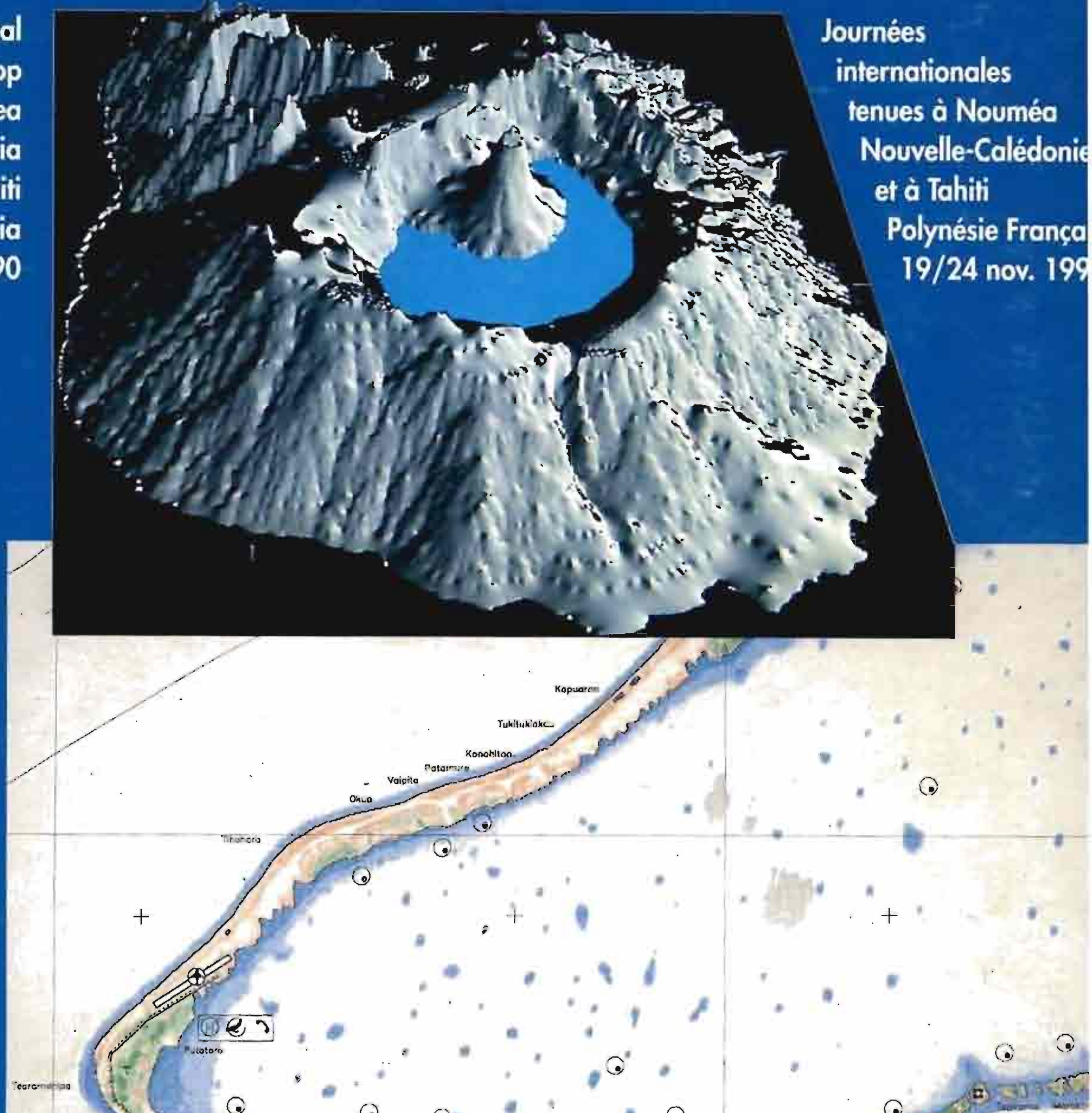
# "PIX'ILES 90"

## TELEDETECTION ET MILIEUX INSULAIRES DU PACIFIQUE : APPROCHES INTEGREES

## REMOTE SENSING AND INSULAR ENVIRONMENTS IN THE PACIFIC : INTEGRATED APPROACHES

International workshop held at Noumea New Caledonia and Tahiti French Polynesia Nov. 19/24 1990

Journées internationales tenues à Nouméa Nouvelle-Calédonie et à Tahiti Polynésie Françai 19/24 nov. 199



ORSTOM

IFREMER

TERRITOIRE DE POLYNESIE FRANÇAISE

# "PIX'ILES 90"

Journées internationales tenues à Nouméa - Nouvelle-Calédonie
et à Tahiti - Polynésie Française
19 / 24 novembre 1990

International workshop held at Noumea - New Caledonia
and Tahiti French - Polynesia
November 19 / 24 1990

ORSTOM

IFREMER

Imprimé par le Centre ORSTOM
de Nouméa
Septembre 1992

ORSTOM Nouméa
REPROGRAPHIE