LANDSAT AS A MANAGEMENT TOOL FOR MAPPING SHALLOW WATER HABITATS IN PAPUA NEW GUINEA

L'IMAGERIE LANDSAT EN TANT QU'INSTRUMENT DE CARTOGRAPHIE EN EAU PEU PROFONDE EN PAPOUASIE-NOUVELLE-GUINEE

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ABSTRACT

Surveys of coastal communities are important in order to establish an inventory of the national resources. The use of an earth resources satellite system (LANDSAT) is demonstrated to contain the spectral and spatial resolution suitable for mapping shallow water communities in tropical Papua New Guinea.

A Landsat multi-spectral image of the Kavieng region of New Ireland island in the Bismark Archipelago was used to map shallow water assemblages. As most of the Pacific is without multi-spectral scanner images, we recommend that a receiving station be established.

RESUME

Les études des communautés littorales jouent un grand rôle dans l'établissement d'un inventaire des ressources nationales. Pour ce faire, il a été montré que l'utilisation d'un système de satellites (LANDSAT) permettait de cartographier les communautés tropicales de Papouasie-Nouvelle uinée, en eau peu profonde. Une image LANDSAT plurispectrale de la région de Kavieng (Nouvelle Irlande), dans l'archipel Bismark, a ainsi servi à y cartographier des zones peu profondes. Comme une majorité du Pacifique n'est pas couvert par l'imagerie scanner plurispectrale, nous recommandons la mise en place de postes récepteurs.

INTRODUCTION

Papua New Guinea (PNG) is a newly independent nation (1975) with a total land area of 461,694 sq km. It consists of the eastern half of the island of New Guinea and a myriad of smaller islands and has a coastline of over 7,000 km. The ocean within the Exclusive Economic Zone (EEZ) of Papua New Guinea, which the government must control and regulate, forms a vast area over seven times the land mass.

To date large areas of PNG's seas are poorly charted (Young, 1982; Done, 1983) and many coral reefs are only just being acknowledged in the scientific literature (Kojis and Quinn, 1984; 1985). The ocean area with Papua New Guinea's EEZ is covered with charts varying from scales of 1:1,700,000 to 1:12,500, the latter for harbours and channels approaches. For general navigation 1:300,000 charts are adequate while 1:100,000 charts are more suitable for coastal naviagation. Table 1 lists the chart coverage within Papua New Guinea's EEZ and the portion of surveyed area on charts of particular scale. Many of the surveyed areas are based on incomplete, erroneous or dated information. Of the 2,339,900 km^2 ocean area only 701,970 km^2 area is covered by a scale suitable for navigation, and only 528,580 km^2 of the latter is surveyed. Much of this area needs to be resurveyed or the existing data verified (Young, 1981). The use of LANDSAT data to create a "HYREGRAPHIC" (Hydrographic Reconnaissance Graphic, 1:100,000 map) to up date hydrographic and bathymetric detail in Papua New Guinea has been suggested by Young (1983a; 1983b).

Fundamental to the administration of the EEZ is a knowledge of the resources located within its boundary, both in type and distribution. Shallow seas and numerous reefs have always proved hazardous for maritime activities and discouraged exploration.

Where developing countries must increasingly rely upon development of their own resources to achieve financial independence, it is important that every opportunity be taken to facilitate exploration. Efficient exploration and development of resources will assist developing countries to achieve prominence in a competitive international marketplace.

Papua New Guinea has large areas of shallow water habitats requiring initial identification or update mapping. As conventional charting methods are slow, hazardous and expensive, alternative low cost rapid remote sensing methods may be employed to provide interim information until surveys by conventional means can be conducted. For example, Quinn (1984) used LANDSAT to monitor the noxious weed Salvinia molesta on the Sepik River, Papua New Guinea. A task that would have normally been done only at great expense and been plagued with logistic problems.

Additionally, strict environmental laws in Papua New Guinea require the monitoring and evaluation of development projects. LANDSAT imagery has already proved useful to help monitor silt deposition associated with a proposed port development (Quinn and Kojis, 1982; 1984).

The use of LANDSAT to map the shallow water habitats such as the Great Barrier Reef was proposed by Smith et al., (1975a; b) and applied by Bina et al. (1978) and Jupp et al. (1981; 1983). The Ministry of Primary Industries in Fiji is considering using LANDSAT to define habitats for giant clam recolonization (Adams, pers. comm.).

The purpose of this study is to assess LANDSAT multi-spectral data for mapping shallow water habitats such as mangrove lined estuaries, coral reef habitats and sea grass beds in Papua New Guinea and to evaluate its potential for use in other developing countries in the South Pacific region.

METHODS

The LANDSAT System

LANDSAT is a satellite designed to establish the value of relatively coarse resolution, large area, reflective multi-spectral imagery from an altitude of approximately 918 km. Sunlight reflected from the earth is separated into four spectral bands. These bands record light of the following wavelengths: band 4, 0.5 - 0.6 µm (green); band 5, 0.6 - 0.7 µm (red); band 6, 0.7 - 0.8 µm (near infrared); band 7, 0.8 - 1.1 µm (infrared). Their contribution to the image is similar to additive color photography, but their separate recording adds a dimension to the interpretation difficult to achieve with photography. Further details of the LANDSAT system are available in Thomas (1975).

The attenuation of light by water is also a strong function of wavelength (Moore, 1980) and the implication for LANDSAT remote sensing can be summarized as follows: Band 4 has the maximum water penetration (15 m) and is most affected by

Table 1: Hydrological Chart Coverage of Papua New Guinea's EEZ (after Young, 1981)

Scale	% Coverage of EEZ	% of area covered surveyed
1: 12,500 - 1: 75,000	1	83
1: 100,000 - 1 150,000	4	69
1: 250,000 - 1: 300,000	25	76
1:1,700,000 - 1:1,000,000	80	79
1:1,700,000 and smaller	100	N.A.

atmospheric scattering. Band 5 is more rapidly attenuated by water and most of it is lost in the upper 5 m. Band 6 contains a part of the red (visible) portion of the spectrum, but a majority of its response is in the near infra-red. In clear, deep water most near infra-red is absorbed within 20 cm of the surface. Band 7 penetrates only the upper millimeters of water, but is useful in plotting heavily silted water. In most situations band 7 is best used to discriminate land from water masses. These signals are, of course, affected by the state of the sea and the atmosphere. It is recognized that LANDSAT can delineate, but not distinguish between the patterns of bathymetry (e.g., Bina et al., 1978) and turbidity (e.g., Jerlov, 1976; Munday and Alfoldi, 1979).

Mapping spatial patterns and signature variations in deep water has been investigated in Australia (Thomson and Carpenter, 1981). Amos and Alfoldi (1979) and Munday and Alfoldi (1979) have compared variations in the LANDSAT signature with actual physical measurements of sediment load in the water column. Wolanski et al. (1984) investigated river plumes and mixing on the waters of the Gulf of Papua and Northern Great Barrier Reef using LANDSAT imagery.

The selective absorption of light by water, molecular scattering and incident radiation all play a role in sea color. The color of turbid water results from the selective absorption by substances carried in the water (Jerlov, 1976). In areas where no component of the signal is confused by sea bottom reflectance, properties of seawater may be studied using LANDSAT data.

The use of LANDSAT on the Great Barrier Reef shelf has shown that when the water is less than 5 m deep, or turbid with concentrations higher than 5 ppm of fine particles, bands 4 and 5 have significant signal levels above background noise (Jupp et al., 1983). In regions of deeper water and/or less turbidity only small variations in band 4 exist making it difficult to delineate depth and water masses and thus requiring repeated images.

Processing Techniques

Computer aided analysis of LANDSAT data uses an interactive programme called LANSAT running on a PDP 11/34 computer at the Papua New Guinea University of Technology. The program was written in Fortran by Dr. Frank Honey to accept data from the Australian LANDSAT Station (ALS). The format of the ALS LANDSAT tapes is band interleaved by line (BIL).

The data from the LANDSAT tapes is transferred to an RK-05 disc, where allocated space allows sub-scenes of 512 lines by 512 pixels to be accommodated. A BASIC program called LSSTOR is used to copy the data from the tapes to the disc from where the information is read off for LANSAT. Each LANDSAT image was enhanced using an algorithm devised by obtaining spectral signatures from several areas with suspected similar physical and biological features.

To display the LANDSAT data an Electohome color display terminal, a Matrox colour display interface was used. Up to 256 lines by 256 pixels may be displayed in 10 colors.

A LANDSAT multi-spectral image from a computer compatible tape imaged by Landsat 3 on 10 August 1981 (path 101, row 62) was used to chart shallow water communities around Kavieng Harbour (2°34'S., 150°47'E.). A record of each image was made using a 200 mm lens on a 35 mm camera and photographing the cathode ray screen. Shutter speeds of < 1/15 sec. were used to eliminate a band effect associated with the cathode ray tube projection.

RESULTS AND DISCUSSION

The Image

Using 10 color bands the habitats around Kavieng are displayed in Figure 1 and codes listed in Table 2. As this scene is just on the horizon of the Australian Landsat receiving station, there is a lot of noise associated with this image that is uncharacteristic of most imagery. Owing to the relatively unsophisticated data processing facilities available, we are unable to "smooth" the image. Many of the single colored pixels some distance away from others of the same color would otherwise be eliminated as they are noise artifacts and not the results of true sensing.

Raw LANDSAT imagery of shallow water habitats such as coral reefs may be difficult to interpret visually. A dark patch may be interpreted as a deep lagoon or sea grass bed or mud flat and a very bright area could be a shallow lagoon with white sand bottom or coral rubble. Wakes around islands can be delinated (Wolanski et al., 1984) any may be confused with turbid or shallow water. It is therefore necessary that classifications be conducted with the aid of someone knowledgeable about the area and post processing surveys be conducted to sample locations to verify classifications at least in the initial stages.

The relative area and surface configuration of each color zone depends on the tidal level during imagery acquisition. A temporal comparison of the band zones of the same shallow water habitat should indicate which areas are subject to the greatest spectral changes during tidal movement.

Sources of Error

There are two major sources of error in mapping shallow water habitats using digital classification techniques. The first is in correctly classifying a pixel as a particular habitat, e.g., coral, and the second is in the accuracy of mapping shallow water habitats where errors will occur from both classification errors and mixed pixels on the field boundary.

The accuracy of classifying the habitats depends upon a number of factors: 1) The ability to discriminate the habitats from other habitats on the dates of acquisition. Submerged reefs look like mildly turbid water and shallow reefs like more turbid water. 2) The training data used to establish class parameters for the classifier must be representative of that class. The best way of ensuring this is to statistically sample enough identical habitats. 3) Setting of the class decision values. If the decision bounds are set too tightly then many pixels that represent the class, but having slightly different response values will not be included and become errors of omission. If the bounds are set too wide then there will be significant errors of commission.

Errors in estimating the areas of the habitats are due to misclassification of individual pixels as well as: 4) Errors in the nominal pixal size. The image was not rectified to ground control hence minor variations in the altitude of the satellite would result in a deviation from the 79 m X 58 m standard. 5) Mixed picture elements on field boundaries. If the percentage of the area of the habitats in the mixed boundary pixels was a uniform distribution and the class decision values were properly set, then there would be negligible errors from this source. However, as the habitats become smaller the distribution of the percentage of each habitat in the mixed picture elements can be expected to diverge from a uniform distribution with an attendent higher probability that errors will occur.

Limitations

LANDSAT can be used to provide reconnaissance mapping enabling effective planning and management of shallow water habitats. Satellite remote sensing does not replace the more conventional methods of shallow water mapping, but can reduce the time and costs associated with them by supplying supplementary data, or data for continuous assessment. This particularly applies to remote, sparsely populated areas which have few trained technicians like Papua New Guinea. Additionally, where data is required periodically over some considerable time the costs of conventional methods would be prohibitive.

The limitation to the application of LANDSAT data exists where there is inappropriate data handling technology and expertise. In the case of LANDSAT there is no requirement for adaption of satellite technology to local conditions as there is no involvement with the sensing equipment or its operations. Involvement is confined to the data produced from the satellite sensing and this can be acquired in a useable state in readiness for interpretation or manipulation. The two main labor intensive activities are in the manipulation and interpretation of the masses of data and in the production of maps charts or statistical data presentations.

Finally, the most immediate limitation to potential users in the South Pacific region is that there is no local receiving station in the region. Hence, signals for less than 1/4 of the waters in Papua New Guinea's EEZ are currently being received and there is no current data from LANDSAT being received over any other area of the South Pacific.

Figure 1: LANDSAT composite image of the Kavieng region, New Ireland Province, Papua New Guinea.

Table 2: Interpretation of Figure 1. Black and white photograph of color LANDSAT image.

Code	Habitat	Depth
1	Deep water	<15 m
2	Deep shoal	8 - 15 m
3	Deep coral	3.5 - 5 m
4	Deep coral and sand	3.5 - 5 m
5	Medium depth coral and sand	0.5 - 3.5 m
6	Sand	0 - 0.5 m
7	Shallow sand and coral	0 - 0.5 m
8	Sea grass beds	0.5 - 3.5 m
9	Mangrove vegetation	
10	Land or clouds	

CONCLUSION

Developing countries do not generally have a satisfactory enough inventory of their shallow water habitats to develop and manage them effectively. General mapping activities, especially within the newly established EEZ, will remain in an unsatisfactory situation for these countries unless priorities alter, special overseas assistance is sought or new alternative technologies are employed.

We believe that satellite based remote sensing equipment such as LANDSAT multi-spectral scanners can make a significant contribution to low cost, synoptic, shallow water resource assessment programs in developing countries with large exclusive economic zones.

The more sophisticated technology found in the thematic mapper in LANDSAT with its narrower band widths and smaller spatial resolution (30 m) will further increase the appropriateness of satellite based remote sensing technology for use the mapping the shallow water resources of the developing countries of the Pacific.

The anticipated launch of SPOT by the Centre National d'Etudes Spatiales, France, in November 1985 will provide an increase in spatial and temporal resolution over LANDSAT imagery and should be evaluated for use in the South Pacific.

RECOMMENDATION

We recommend: 1) that two SPOT image receiving stations be established in the South Pacific, 2) that these stations be placed in the region of Tahiti and New Caledonia, and 3) that SPOT products be freely available at reasonable rates to all nations of the South Pacific.

Considering France's use of its Pacific colonial territories as an experimental ground for its nuclear program and the concern this aroused with respect to nuclear contamination in the South Pacific, we feel it appropriate that the establishment costs for the receiving stations be borne entirely by the French government.

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