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Claasen, D. van R., 1992. The Utilisation of Remote Sensing in the South Pacific. ACIAR Technical Reports No. 19, 59p.

ISBN 1 86320 059 2

Typeset and laid out by Arawang Information Bureau Pty Ltd, Canberra, Australia.

Printed by Goanna Print Pty Ltd, Canberra, Australia.

Cover: Remotely sensed data have many mapping and land resource management applications. This image of Trobriand Islands, Papua New Guinea, shows approximate water depths. Shallow water (0–0.5 m) is depicted in pink and increasing depth of water in red, green, brown and yellow. The image was developed by the Australian Surveying and Land Information Group (AUSLIG) from LANDSAT data using the microBRIAN image processing system. The algorithms used to interpret the data are the product of research by the CSIRO Division of Water Resources.

The Utilisation of Remote Sensing in the South Pacific

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Great Barrier Reef Marine Park Authority,
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Australian Centre for International Agricultural Research
Canberra 1992

Contents

Acronyms and Abbreviations

ADB	Asian Development Bank
AIDAB	Australian International Development Assistance Bureau
AKCLIS	Australian Key Centre for Land Information Studies, UQ
AUSLIG	Australian Surveying and Land Information Group
BDDP	British Development Division in the Pacific, UK
CCOP/SOPAC	Committee for Coordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas, now renamed SOPAC.
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
DSIR	Department of Scientific and Industrial Research, NZ
DTCD	Department of Technical Co-operation and Development, UN
DWR	Division of Water Resources (CSIRO)
EC	European Community
EEZ	Exclusive Economic Zone
ESCAP	Economic and Social Commission for Asia and the Pacific (Bangkok, Thailand)
FAO	Food and Agriculture Organization
FFA	Forum Fisheries Association
GBRMPA	Great Barrier Reef Marine Park Authority
GIS	Geographic Information System
GRID	Global Resource Inventory Database (UNEP)
ICC	Intergovernmental Consultative Committee, ESCAP RRSP
IFREMER	Institut Francaise de Recherche pour l'Exploitation de la Mer (French Oceanographic Institute)
IMR	Institute of Marine Resources, USP
INR	Institute of Natural Resources, USP
IPF	Indicative Planning Figure (UN)
LATICAL	Laboratoire de Traitement d'Images Caledonien (ORSTOM, Noumea)
LDC	Least-developed Country(ies)
NWFC	Nadi Weather Forecasting Centre, Suva, Fiji
NZ	New Zealand
ORSTOM	Institut Francais de Recherche Scientifique pour le Developpement en Co-operation
PFF	Project Formulation Framework
PNG	Papua New Guinea
PRODOC	Project Document
PTF	Pacific Trust Fund, AIDAB/UNDP
RIS	Regional Information Service of the RRSP, UN
RMIT	Royal Melbourne Institute of Technology
RRSP	Regional Remote Sensing Programme, UN
SI	Solomon Islands
SOPAC	South Pacific Applied Geoscience Commission
SPAS	School of Pure and Applied Sciences, USP
SPC	South Pacific Commission (Noumea, New Caledonia)
SPOT	Satellite d'observation de la Terre
SPREP	South Pacific Regional Environmental Programme
SPT	Station Polynesienne de Teledetection (Papeete)
SSED	School of Social and Economic Development, USP
TCDC	Technical Co-operation among Developing Countries
TPR	Tri-partite Review
UFP	Universite Francaise du Pacifique
UN	United Nations
UNEP	United Nations Environmental Programme (Nairobi, Kenya)
UNDP	United Nations Development Programme
UNDTCD	United Nations Department of Technical Co-operation and Development
UQ	University of Queensland, Australia
USAID	United States Agency for International Development
USD	United States Dollars
USP	University of the South Pacific (Suva, Fiji; Apia, Western Samoa)
WMO	World Meteorological Organization, UN

Summary and Introduction

THIS is the final report to the Australian Centre for International Agricultural Research (ACIAR) on the use of remote sensing in the South Pacific.

The consultancy commenced on 9 November 1990. The mission visited South Pacific, New Zealand and Australian national and regional agencies, institutions and other centres. The consultant also attended an AIDAB/UN–ESCAP-sponsored working group meeting on remote sensing issues in Suva, Fiji in March 1991.

Background to consultancy

Remote sensing can be described as the interpretation of aerial photography and satellite images to acquire earth resource data. The objective is to provide information on the distribution, quality and quantity of natural resources for the management of terrestrial and marine resources.

Over recent years Pacific island country governments and some regional organisations have shown increasing interest in the use of remotely sensed data to acquire present status information on natural resources. This has been expressed through a number of regional workshops and bilateral requests for training and assistance with pilot projects.

The main response in the mid to late 1980s came from the UNDP/ESCAP Regional Remote Sensing Programme (RRSP) and trial applications research within the South Pacific Applied Geoscience Commission (SOPAC).

In 1990 the South Pacific Commission (SPC) wanted to obtain a small image analysis system to assist their Inshore Fisheries program. There was a distinct possibility that funding for such a system might be provided by the European Community (EC). SPC believed there was merit in a consultancy to investigate SPC's internal needs for remote sensing and geographic information systems. The consultancy terms of reference, to be funded by the EC, specified the extent of the investigation. It also requested the consultancy assess how such a facility could service the remote sensing needs of SPC member countries, if established.

The Commission also asked ACIAR to provide a technical specialist on remote sensing applications to assist the investigation. ACIAR agreed to support this request. It directed that the consultancy address Australia's role in any future remote sensing development in the Pacific. The Great Barrier Reef Marine Park Authority (GBRMPA) provided the consultant, Mr D. van R. Claasen, to conduct the assessment separate to, but coinciding and cooperating with, the EC mission.

Aims and scope

ACIAR asked the consultancy to provide the necessary background information to assess any remote sensing related proposals submitted for the Pacific.

The consultant was directed to interact with the EC team and, as necessary, visit relevant organisations and institutions in Australia, Fiji, French Polynesia, New Caledonia and New Zealand. It was also agreed that the final report include mention of the findings of the AIDAB/UNDP–ESCAP RRSP working group meeting on remote sensing and geographic information systems (GIS) in the Pacific.

Terms of reference

The terms of reference (TOR) requested that the consultant address and report on:

- the current use of remote sensing techniques in the field of fisheries and coastal resources management (agricultural/environmental) in the South Pacific;
- the opportunities for research and development for ACIAR in collaborative research using remote sensing facilities;
- the feasibility of establishing a remote sensing facility in the South Pacific Region such as proposed at SPC;
- the likely cost of using such a facility by potential clients and, therefore, the implications of aid funds needed to use it; and
- the likely input of Australian remote sensing research institutes to the facility.

The consultancy included the following:

- 9 November–14 December 1990. Investigatory Mission to selected Pacific destinations. Coordinated by Mr S Kofe, Development Economist, South Pacific Commission.
- At SPC's request the ACIAR mission interacted closely with the EC Team. In accordance with the ACIAR TOR and the SPC itinerary the joint mission visited Noumea (New Caledonia), Papeete (French Polynesia), Christchurch, Wellington and Palmerston North (New Zealand), Suva (Fiji) and Brisbane and Canberra (Australia).
- A number of Pacific Island Country representatives attending the Pix–Iles Remote Sensing Workshop were interviewed. The workshop was organised by the Institut Francais pour la Recherche en Mer (IFREMER) and the Laboratoire de Traitement de Images Caledonien (LATICAL/ORSTOM).
- 18–22 March 1991. Attendance (at no cost to ACIAR) the AIDAB/UNDP–ESCAP Working Group Meeting on Remote Sensing and GIS for the Pacific, Suva, Fiji.
- Literature review of recent studies conducted by or for regional and international multilateral organisations. These include specific references supporting positive aid intervention to integrate remote sensing and GIS procedures and technology with operational resource management proposals (Claasen, 1990; UN–ESCAP, 1990a, 1990b; Hill and Pernetta, 1988; SOPAC Proceedings of Technical Meetings, 1987–89; Tortell, 1982, and Wilson et al., 1986).

Findings

Major constraints to efficient natural-resource management and environmental planning in the South Pacific include:

- inconsistent delivery of timely, acceptably accurate and appropriate information on the quality, quantity and distribution of resources to decision makers and planners; and
- scarcity of integrated data on natural resources and the environment in a form which clearly conveys the salient facts to decision makers and planners.

These constraints are, in part, caused by:

- scarce resources—small countries have a small natural and human resource base with many demands, too many projects and activities in each country;
- shortage of staff trained in manual and computer-assisted processes to interpret air photography and satellite data and handle geographically coded data and information;
- poor infrastructural capacity to absorb remote sensing technology; and

- lack of awareness of benefits and cost-effectiveness of remote sensing and geographic information systems to management.

Current use of remote sensing

There is extensive interest in, and a growing intra-national and intra-regional trend towards the acquisition and application of geographic information and supporting image analysis systems technology. The trend is supported by a global trend towards more powerful and reliable software and hardware at reasonable cost.

Current use of remote sensing is restricted to a few applications. Most of these use interpretation of conventional black and white aerial photography for topographic, land-use planning, mining, forestry and some fisheries purposes. Cost constraints inhibit even the use of off-the-shelf photography for a number of departments in some countries.

There is therefore a reluctance to experiment with new uses and forms of remotely-sensed data analysis as they are perceived to be more expensive and not useful to Pacific conditions.

Representatives of all countries acknowledge a need to demonstrate and publicise proven applications of remote sensing appropriate to the Pacific. There are three areas which should be addressed if the Pacific Island Countries are to become more self-reliant in rapid natural resource data acquisition:

a) technical cooperation and coordination between the countries of the region to ensure the orderly and effective transfer of the technology to user groups;

b) education and training opportunities within each country and within the region; and

c) applications research, to prove the technology within the region, and practical assistance in the development and in-country implementation of applications projects.

There is therefore scope for programs which will:

- promote and coordinate technical cooperation and development of remote sensing and GIS applications projects and project support between countries;
- provide access to basic and specialised training in remote sensing and geographic information analysis techniques and technology;
- provide cooperative mechanisms to strengthen and/or develop sub-regional and national capabilities to monitor and assess natural resources and environment through practical applications research.

Feasibility of a dedicated regional remote sensing facility

The increasing interest in, and growing application of high-technology remote sensing in the Pacific does not necessarily justify establishment of a centralised regional support facility.

The future pattern of development will consist of decentralised microcomputer-based image analysis systems located in regional organisations and some national agencies. Some larger systems will be installed: e.g. Papua New Guinea and Fiji to join the IFREMER/SPT and ORSTOM/LATICAL systems already in the region. Operators of smaller systems may occasionally need bureau services (for large projects, high-quality map and/or image production).

Recent studies (Mau 1991, Collotte and Meijere 1990, Claasen 1990) confirm an adequate supply of high technology remote sensing equipment and services available in existing institutions in Australia, the French Territories or New Zealand. There is a need to make those services more accessible to the users.

The cost of establishing, operating and maintaining an additional, fully equipped remote sensing and GIS centre appears to be prohibitive and superfluous.

Research opportunities

The scope for applications research and technology transfer in the topical area is considerable. It should, however, focus on practical application(s) not the remote sensing technology alone. The South Pacific must have an increase in the number of resource specialists (e.g. land-use planners, foresters, environmentalists, fisheries managers) who can effectively use the technology to further their own assessment and monitoring needs.

There is need for projects and programs which foster the integration of the technology as and when, and at the level, appropriate for operational work programs of the regional and national resource and planning agencies.

The focus of research should be to compare techniques and applications, prove or disprove their applicability in the Pacific context, and transfer those that are successful to the operational areas.

Projects which should be supported are those which meet a continuing need for reconnaissance surveys e.g. nearshore and coastal fisheries habitat with the South Pacific Commission's Nearshore Fisheries program as the regional partner, and/or designed to develop common approaches, common definitions and standards and transferable methods (AIDAB–UQ–Queensland Department of Lands South Pacific Air Photo Manual.

The rationale behind these projects is:

a) the techniques to assess shellfish (trochus, giant clam, black-lip pearl) habitat have been successfully developed and appear ready for operational use. The project would need to answer two questions: can the techniques be generally extrapolated to all the South Pacific Island Countries, and can the process be incorporated cost-effectively and efficiently into a practical operational program environment, i.e. provide information useful for stock assessment and planning; and

b) an air-photo interpretation manual for the South Pacific which uses specific South Pacific examples would aim to increase productivity of government officers involved in planning and natural resource management and provide training institutions in the Pacific countries with a teaching resource.

Potential costs

The terms of reference asked for an estimate of costs to potential clients using a regional facility. In essence, these would be of the same order as if clients were to use services provided by existing institutions and vendors in Australia, the French Territories or New Zealand.

Costs are determined by the type of project, the type of services requested in relation to that project, and the desired end-product quality. It is difficult to be definite about costs without this information. Costs could range from less than $10 000 to purchase satellite imagery with some basic enhancements, to more than $500 000 for major remote sensing based inventory projects.

Input of Australian remote sensing institutions

Regardless of the eventual mechanism, the opportunities for the involvement of Australian remote sensing research institutions is considerable. Some institutions are already involved in joint research, training and educational activities. These include, *inter alia*, the Australian Key Centre for Land Information Studies (AKCLIS) with UN–ESCAP RRSP and the University of the South Pacific (USP), SOPAC and the Government of Fiji; James Cook University (JCU) with PNG University of Technology, USP and SOPAC; and the Remote Sensing Centre of RMIT with the Government of Tonga.

Australia has supported a number of fisheries, forestry and land-resource inventory projects which use remote sensing data. They involve elements of CSIRO (Division of

Fisheries, Division of Tropical Crops and Pastures, Division of Water Resources). These could be increased.

The recommendations made by the Remote Sensing Working Party to the Australian Space Board are worthy of review particularly as they relate to international collaboration in the provision of '... a collaborative mechanism for identifying and solving common regional problems and to cement our market position in the region' and '... participation in global and regional environment and climate research, monitoring and management programs'. Such collaboration should include New Zealand and French Territorial institutions.

There could be greater involvement by tropical environment, resource and marine institutions in applying their expertise to the problems and issues faced by the Pacific. The common constraint is the very real shortage of funds in the Pacific to initiate such research. As Australian institutions lack discretionary funding to consistently apply their undoubted knowledge to Pacific problems it is up to the regional agencies backed by applied research donor centres such as ACIAR to provide the objectives, linkages, coordination and, if necessary, the money.

Recommendations

In an assessment of this nature it is difficult to make any concrete recommendations regarding future action. There are however some suggestions which would assist in maintaining an adequate information base to assess possible activities which ACIAR might be asked to support or initiate.

ACIAR should:

a) maintain a watching brief on Australian and Pacific proposals for regional cooperation in remote sensing applications research and technology transfer;

b) encourage and support in principle the development of any regional Technical Cooperation and Development Network program, as proposed by SPC/EC, UNEP/SPREP, AIDAB/ESCAP evaluations, as appropriate;

c) continue to support projects which incorporate remote sensing in operational programs such as the ACIAR/CSIRO Baitfish Project; and

d) investigate new joint proposals to incorporate remote sensing in operational projects (e.g. SPC Fisheries Habitat Mapping project).

Remote Sensing in the Pacific

Remote Sensing Concepts and Techniques

Basic concepts

The theory and practice of applied remote sensing will not be covered in any detail by this report. There are some useful basic reference texts which may be consulted (*Manual of Remote Sensing*, Colwell, R.N. 1983).

Remote sensing is the capture of data from regions of the electromagnetic spectrum through the use of instruments which do not come into contact with the features of interest, together with analysis and manipulation of the data to facilitate interpretation (Fisher and Lindenberg 1989).

The term as used in this report focuses on the latter aspect, more specifically:

- the interpretation of aerial photographs and electronic multispectral scanner (MSS) images in order to acquire information about the quantity, quality and distribution of terrestrial and marine resources.

This definition includes both traditional and new uses of conventional panchromatic (black and white) and colour aerial photography and airborne and space satellite MSS data.

Remote sensing interpretation methods

There are three basic methods used to map resources using remotely sensed data:

- simple visual interpretation of standard black and white, colour, or false colour (photographic infrared) photographs;
- visual interpretation of photographic products which have been enhanced for easier interpretation by photographic or computer-assisted digital techniques; and
- production of photo-maps or thematic maps, statistical and attribute tables from computer-assisted analysis and classification of computer-compatible data recorded by electronic scanners.

The objective of remote sensing

The objective of using remote sensing in a resource management context is to provide information about terrestrial and marine resources in a form readily understood by end users.

Information is needed to assess land and sea resources for their ability to support or absorb alteration and disturbance. Spatial and temporal characteristics of resources are important in resource assessment. Resources are located and used in time and space, that is, the resources are distributed over a land- or sea-scape. Over time the quantity, quality and distribution of the resources change as a result of human or natural causes. The resource assessment process tracks these changes using the tools of geographic analysis.

Examples of the type of geographic analysis planners and managers are required to perform, for example, include:

- multi-factor overlay or 'sieve' mapping for land–sea resource capability, suitability and vulnerability;
- prescriptive control assessment (zoning for land-use planning);
- risk assessment for flood and/or landslide vulnerability (essential in high mountainous islands frequently subjected to natural disasters from storms and cyclones;
- crop production assessments (annual production estimates; forest monitoring); and
- change analysis (agricultural census analysis; routine post-disaster assessment).

Aerial photo and, increasingly, satellite-image interpretation is a standard data collection tool.

Appropriate technology

The question is often asked why countries need a sophisticated technology to map areas which have

already been mapped. Is this not a needless expense to obtain apparently superfluous information? Such observations ignore the reality of very rapid land-use changes.

Sound resource-planning decisions require present status information at less than two-year intervals (McQuillan 1975). National map revision programs in developed countries cannot meet this demand. In developing countries the interval varies from six to more than ten years. This is inadequate by any standards.

Current status information can be expensive to collect. Considerable research attention has therefore focused on developing more cost-effective and efficient methods of data collection. This has led to the development of rapid land and sea resource survey, assessment and monitoring processes. Remote sensing techniques are central to rapid data collection.

Applicability in the Pacific

Research, applications research and operational programs have shown that remote sensing is effective in environmental conditions prevailing in the Pacific island countries.

Pacific island surveying and mapping agencies recognise that aerial photography and satellite imagery do offer more cost-effective delivery of up-to-date information. In some cases, such as reconnaissance mapping of shallow water marine areas, satellite data can acquire information which would be too expensive to collect in any other way. Despite this, the effective transfer of the technology to national resource agencies has not been entirely successful.

The findings of the UNDP/ESCAP remote sensing workshop on *Remote sensing for land and sea resource survey and evaluation in the Pacific: applications, coordination and training* (ESCAP 1990a) are particularly significant. Senior level technical agency representatives from countries participating in SPC, SPREP and ESCAP RRSP programs strongly recommended that special efforts be made to develop a sustained training, education and project support services program in manual and computer-assisted air-photo interpretation and remote sensing techniques and technology for the Pacific countries. This was further endorsed by the final report on the sub-program (ESCAP 1990b), the Pix–Iles Workshop and, most recently, the AIDAB/ESCAP RRSP workshop in March 1991.

RRSP-sponsored national seminars in Tonga (February 1990) and Fiji (March 1990) also stressed the need for adoption of the technology and training.

The technology has now developed to a point where even small agencies can use it reliably. Large facilities with expensive equipment may be necessary to produce high-quality maps and images. They often, however, do not have the local knowledge and familiarity with the resources to make the final products more than superficially useful to end users. Therefore national resource specialists will have to become more involved in the development of remote sensing. It cannot be assumed that useful information can be automatically provided by external sources.

If the Pacific countries, with a range of natural resources, such as land, water, fisheries and forests, are to manage their development properly and efficiently, they must explore new and efficient methods. Remote sensing and satellite imagery are a prerequisite for this.

On the ground, resource assessment specialists can only cover small areas. There is a continuing need to know what the situation may be over the whole of a sub-division, nation or region if the land and sea resources are to be properly managed. If localised and detailed ground-truthing work can be extrapolated to large areas there is a great potential to save considerable time and expense. Remote sensing is no substitute for detailed field work. It does, however, allow selection of areas in which that fieldwork would be most useful. It can also provide the preliminary 'broad-brush' estimates necessary for forward planning.

Ratu Tui Cavulati, Deputy Secretary of the Fiji Primary Industries Department outlined one example[1] — the Fiji Fisheries Division spent four years on an extensive field survey of giant clam stocks in Fiji waters. The Division suspected that giant clams were being over-exploited as early as 1983. It was not until 1989 that sufficient evidence was obtained to justify legislation banning the export of giant clam meat. It was clear quite early in the survey that giant clams had a fairly specific habitat defined by water depth, turbidity, presence of coral outcrops in lagoons and exposure to prevailing winds and waves. Such information was not readily available from existing charts and aerial photographs. Satellite imagery could have provided an early assessment of the available habitat. This, combined with results from the first ground surveys, could have allowed an estimate of standing stocks for comparison with the export volumes. Controls on the fishery could have been recommended and instituted as early as 1986. By 1989, the only option available was a total ban on exports. It is likely to be ten years before stocks of the larger giant clams recover enough to be fishable at commercial levels.

[1] Government of the Republic of Fiji: Remote sensing seminar for decision makers, 30 March 1990, Suva, Fiji.

He went on to outline the many other ways in which remote sensing could be useful to the fisheries sector including sea-surface temperature mapping, mangrove area and type mapping, sedimentation analysis to predict effects on freshwater clam productivity, aquaculture site selection, fishing rights delineation and navigation, and selection of seamounts.

Development Issues

There are some general influences on the development and application of science and technology in the Pacific island countries which are pertinent to any discussion dealing with remote sensing technology transfer. These are dealt with under the general heading of development issues.

The need for information

The need to provide information quickly has become more acute as the pace of development in the Pacific has increased. Governments have to incorporate growing pressures for development (participation in a cash economy), increased pressures on the resource base, increased population mobility, pressures for increased social services, etc., and must have access to acceptably accurate information.

Development studies consistently report that country agencies encounter significant difficulties in obtaining up-to-date information for natural resource planning and management.[2] The constraints are not restricted to remote sensing data. They apply to all resource data storage and accessibility. The principal difficulties appear to be:

- limited internal operational capacities to acquire, analyse, store, recover, integrate and handle data on the quality, quantity and distribution of natural resources; and
- shortages of staff trained in manual and/or computer-assisted processes and techniques to collate, assess, integrate, handle and store data to support management of natural resources and the environment.

The amount of information available in the Pacific countries is actually quite extensive. It is, however, not easy to locate or access as and when needed.

The critical issue is efficient data management. These organisational constraints to efficiency must be solved if countries are to be more self-reliant in environmental and natural resources development planning, management and monitoring. Another major factor is the timeliness of data. Often, even when data are obtainable they are not up to date. The most cost-effective means of ensuring temporal accuracy is to use remotely sensed data in survey and monitoring.

Constraints to information management

There are geographic, institutional, economic, and human resource factors which affect the South Pacific countries in general, and the delivery and incorporation of natural resource and environment data in the development process, in particular. The same factors restrict the adoption of improved technologies to process such information.

Geographic factors The Pacific region contains 22 island countries or territories, encompassing about 552 000 km^2 of land within 23 850 000 km^2 of oceanic waters within the combined EEZ. The population size varies from 3.5 million (PNG) and Fiji (750 000) to as few as 1600 (Tokelau). These parameters produce development constraints which apply generally.

The vast distances create considerable logistic, communications and transport difficulties. They dominate economies and inter-country activities and have implications for any project—program developments originating both within and outside the Pacific.

The isolation of the sub-region and countries from the world community is real. The design of programs to assist these countries must consider their special nature. Locally appropriate solutions, sensitive to political, administrative, institutional and social factors peculiar to the region and to individual countries, are needed.

Pacific island countries have tried to solve the constraints created by these characteristics through regional cooperation in applied research, training of personnel and the sharing of expensive equipment, expertise and experience.[3]

Institutional factors The multi-national, small-state structure of the sub-region puts supply, operation and maintenance of fully developed remote sensing

[2] The accessibility of information and availability of skilled manpower are broad-based issues. Wilson et al. (1986), supported by statements in many national development plans, noted decision makers perceived a clear need for information resources, and the development of appropriate technological information systems to assist decision makers was an issue of key importance.

[3] Recognised in the Pacific by the specialised sub-regional agencies — South Pacific Commission (22 countries); South Pacific Forum Secretariat (22); Forum Fisheries Association (22); South Pacific Applied Geoscience Commission (10); SPREP (22) — and some educational institutions [University of the South Pacific (11)]. Many UNDP-funded projects are regionally oriented and cover atoll development, water resource and fisheries.

and geographic information technology beyond the institutional resources of many of the smaller island states.

Pacific countries fall within three groups:

- those too small to have the necessary institutional capacity or requirement for the technology;
- those which could benefit from the use of the technology but do not have the infrastructure to fully support it; and
- those with both the need and the infrastructure, at least potentially, to establish and maintain successful facilities.

Very small countries need the support of a sympathetic remote sensing support service which would produce information on request. Users of information in these countries need to be able to interpret the products and reports generated by such services. A regional facility could perhaps service this need although demand would not be high.

Larger countries will benefit from installing small decentralised database management systems with remote sensing and graphic display capabilities. Such countries are characterised by institutions which have low capacities to absorb new technology (e.g. the relevant institution(s) consists of one or two specialist staff with no immediate prospect of expansion). They will not generally set up a national remote sensing or GIS capability. These countries may need external support of sub-regional, regional or bilateral facilities. Demand would be moderate.

The third category consists of countries capable or potentially capable of self-sufficiency in image analysis and GIS and allied technologies. These need human resource development, i.e. training and facility establishment assistance programs. They would be unlikely to have a long-term need for a regional facility.

Although many Pacific Island countries are very small and have low populations this does not necessarily mean sophisticated technologies to manage their resources are inappropriate.

The land masses of some island nations approach, and in the case of Papua New Guinea exceed, those of the smaller European nations. The major shallow water (reef lagoons, shoals, sea-mounts) areas of the Pacific nations are even greater in extent. These areas are a major food source and, in terms of tourist and fishing stocks, economic resource. Together the areas to be assessed and managed are vast, isolated and logistically difficult to survey.

Low population numbers support a case for cost-effective and efficient monitoring and assessment methods. Scarce skilled staff coupled with large and/or isolated management areas demand techniques and tools which can increase staff productivity. The most appropriate technology in some developing countries, provided it can be effectively absorbed, may in fact be 'high' technology.

It is, however, essential to consider the specific needs of each country and institution. A tool should not be used merely because it exists, it must be suited to the required task.

The desire of countries for better processes, including higher technologies, must be taken into account. One should avoid any semblance of the paternalistic approach which decides issues on a 'we know what is best for you' basis.

Economic factors Poor economies restrict the capability of countries to invest in new technologies. They are not in a position to 'experiment' and are reluctant to adopt the technology when its worth has not been demonstrated. Scarce funds also restrict educational capacity and opportunity, particularly in science and technological sectors. These conditions imply a continuing reliance on external assistance for higher technological advances.

Kiribati, Western Samoa, Tuvalu and Vanuatu are numbered among the 'UN Least Developed Countries' category and may qualify for special assistance.

Human resource factors Effective geographic-data analysis and information processing and the capacity to absorb technology is constrained by the lack of trained and experienced staff.

The application of management information technology and processes to natural resource and environment management has developed rapidly in recent years. Pacific governments and institutions have expressed great interest in these developments. A number of countries have developed or are developing GIS or resource database management systems with computer-aided mapping capabilities to store the necessary data and produce maps.

Many systems lack user-friendly modelling and analysis components for specific assessments. They do, however, represent an important stage in the development process and provide digital, i.e. computer-compatible data sets which can be used to effect in sub-regional, regional and global data.

Paradoxically, even though there is strong support for improved data management, the direct relevance of remote sensing and geographic information processing has not been universally demonstrated. Technical specialists in the mapping, survey and some resource sectors want the technology. Upper management is not yet totally convinced.

The relatively slow adoption of complementary facilities by regional agency resource managers is

surprising. Sub-regional institutions and specialised agencies (SPC, SPREP, SOPAC, FFA, USP) have only recently started evaluating remote sensing and GIS in relevant program areas.

There is need for applications research to prove that working solutions developed elsewhere can be applied in the Pacific environment. There is also a need to develop air-photo interpretation keys and appropriate manuals which address Pacific issues and use Pacific examples.

There are few reliable avenues in the Pacific for training (and re-training) in applied remote sensing. This is especially true for those without the necessary qualifications for tertiary training in the developed countries. The opportunities for non-graduate level technician training are limited and declining. This severely restricts a more rapid adoption of resource assessment and monitoring support techniques.

At present, national staff needing training in these or related techniques must go to institutions in developed countries (Australia, France, Holland, New Zealand). This costs money, the agency loses a scarce staff resource for up to four years, and restricts the number of persons who can be trained. There is often no guarantee that graduates will remain with the agency long enough to warrant the investment.

Need for self-reliance Pacific island governments want to increase their internal capabilities in natural resources and environment survey, assessment and monitoring processes (ESCAP 1990a). Increasing pressures, e.g. exploitation of forests and fish stocks through population growth/economic growth, and increasing numbers of proposals for development projects and programs make this a priority area for development.

Whenever environmental or natural resource information is needed for development planning or impact assessment purposes it is often necessary to use outside specialist consultants to conduct the surveys. Consequently, there is a substantial and continuing leakage of national and/or aid funds back to the industrial countries where such expertise is obtained. Few of these externally funded and staffed projects provide the sustained training and support effort essential to effective technology transfer.

Technical capacity Agencies responsible for map production, even in countries with good to acceptable cartographic facilities (e.g. Fiji, Papua New Guinea, Solomon Islands, Vanuatu, Western Samoa) often find it difficult to obtain finance to replace or modernise equipment. In consequence, the equipment depreciates, there is a corresponding loss of productivity and, if not corrected, loss of capacity to fulfil agency functions. This is a budgeting and infrastructure problem. The technical capacity is proven.

In general, given some assistance, experience to date shows that '... systems can be installed and training provided so that, for the most part, only minor problems are experienced in operation. Major faults (with careful selection of equipment, etc.) rarely arise. Thus, the need for specialist technical support is rare and does not require costly, permanent in-country support. Nevertheless, this constraint must be overcome when the need arises' (McAlpine and Hunter 1990).

The long-term viability of systems therefore lies with software and hardware maintenance support and the provision of opportunities for initial and re-training as staff are turned over and/or equipment and techniques change.

Nature of data The amount of scientific and environment data for the Pacific with a spatial dimension is extensive and diverse. The data covers resource availability and distribution at regional to local levels and scales. The information is located in the Pacific countries, regional specialist agencies, and in research and implementing institutions in developed countries.[4] Poor storage and data pooling mechanisms mean the data are not maintained or kept up to date. This is wasteful. When the data finally are needed this often results in a complete new inventory or survey with all the attendant costs. Local capacity to update natural resource maps on a continuing low-level basis is much more efficient and less costly.

User Groups

A more detailed description of the current status of applied remote sensing and geographic information technology in the Pacific is provided in Appendix 1. In general, and it must be said that the situation is changing rapidly, Pacific island country institutions lag significantly in the routine application of air-photo interpretation, remote sensing and geographic information systems to support resource development and environmental management (ESCAP 1990a, b).

[4] Australia, New Zealand, United Kingdom, and France research agencies of colonial and post-colonial activity; aid programs, academic cooperative research programs, etc. (see also Hill and Pernetta 1988).

Pacific island government agencies

A number of Pacific island countries are establishing development planning and environment-oriented geographic or resource information systems.[5]

There are, however, comparatively few staff with remote sensing and GIS applications skills. Most are located in survey and mapping with a few in environment, planning and natural resource management departments. The use of geographic evaluation procedures, with or without GIS, for natural resource mapping and monitoring is somewhat limited as a result.

Intra-national and regional program coordination of data acquisition projects, using some form of remote sensing, is poor. This often results in costly duplication of effort. A consequence is that many environment and resource development projects proceed with inadequate resource data.

Some countries (PNG, Fiji, Cook Islands, Samoa, Vanuatu) are actively implementing or investigating national resource information database systems. However, facilities and programs in the Pacific are generally specialised and not designed for integrated national planning. This is particularly true for familiarisation, introductory and advanced training and longer-term education in advanced air-photo and satellite image interpretation and GIS techniques and applications within either educational institutions or government infrastructures.

The strong interest in GIS notwithstanding, a specific constraint to the development of fully operational systems in the Pacific is the issue of temporal precision (McAlpine and Hunter 1990). A GIS which is not regularly updated can become a liability to sound decision-making. Such corrections can either be achieved through the 're-inventory' of an entire area or nation at regular intervals (e.g. 5-year census intervals) or through regular incremental monitoring. The latter is the preferred route when dealing with natural resources.

The use of remote sensing-based sampling surveys on a consistent if opportunistic basis (i.e. as and when cloud-free images become available) is the only feasible cost-effective monitoring technique for large areas. The principal constraint to this is the lack of facilities and trained manpower to access and analyse imagery.

The question of technical back-up must be addressed. While the need may be rare and would therefore not warrant permanent in-country support, there must be an avenue to obtain specialist technical back-up for difficulties and faults encountered in relation to specialist hardware and operating and applications software.

Other aspects of operational GIS which still need to be addressed include issues related to resource productivity potential. It needs both short- and long-term research into basic resource performance and must consider models which can assess Pacific island resource types and user patterns. Appropriate data models and computer software must be developed to solve the problem of turning relatively complex computer manipulations into 'user-friendly' programs which reflect a view of the environment and its uses as perceived by planners of the developing countries.

The Pacific nations recognise the vital role of GIS, air-photo interpretation and remote sensing in resource use planning. GIS are being established at the national level but operate under constraints which could best be addressed by a joint regional network with adequate support facilities. This would allow small nations, which will need and develop environmental monitoring and assessment systems but are unable to support '... all the technical components in their development and maintenance ... to derive some of the economies of scale that accrue to GIS operations in larger nations by developing collaboration mechanisms across the region' (Hill and Pernetta 1988).

There are real and significant differences between each of the Pacific island countries and their respective needs for remote sensing applications, training and facilities. The following conclusions, however, can be drawn.

Some conclusions

Use of remote sensing

- Some countries have considerable internal capacity to acquire conventional air-photo data, prepare information, carry out cartographic drafting work, and print and publish maps, but need to improve inter-agency coordination in area surveys and data dissemination from completed surveys. Other countries still need to develop this capacity.

[5] Papua New Guinea has PNGRIS (PNG Resource Information System — developed by Australia's CSIRO) and a land information system (LIS — land parcels, ownership, services data). PNGRIS has a map output but no spatial modelling capability; Fiji has recently installed a land information system (INFORMAP on a micro-Vax) with geographic mapping capabilities at the Native Lands Trust Board (NLTB) for customarily owned lands, but it is not in use as a GIS at present. Fiji also proposes the establishment of a cadastral LIS; Western Samoa has two GIS, one developed as a result of an ADB project (land use and resource inventory— using Arc/Info) and the Geneva-funded GRID SACOGIS (Samoa Coastal GIS); Cook Islands (Arc/Info), Solomon Islands and Vanuatu have commenced projects to develop respectively a land-use information and forest inventory systems, the latter based on PNGRIS (same capability).

- Remote sensing, particularly the use of air-photo interpretation, is used to some extent in most Pacific island countries.
- There is a growing trend to use satellite image interpretation in a number of agencies of the larger nations. The trend is accelerating and it is expected that most countries, excluding only the micro-states, will acquire some form of minimal manual air-photo and satellite-image interpretation facilities within the next five years.
- While there are only four image analysis systems in the Pacific–SOPAC, Fiji; the National Weather Forecasting Centre, Nadi, Fiji; and the major IFREMER/French Polynesia Remote Sensing Station and ORSTOM/LATICAL Remote Sensing Centre Facilities in Papeete and Noumea respectively — the trend towards more powerful microcomputer image-processing systems at lower prices will allow micro-state governments and government agencies in the larger countries to acquire image processing and geographic information technology in their own right.

Benefit–cost demonstrations

- There are few studies demonstrating the contribution cost-effective and accurate applied remote sensing can make to operational natural resource management programs in Pacific environments— consequently there is need for rigorous research into transferability of proven techniques between countries of and from outside the region.

Constraints

- The increasing interest in remote sensing and, particularly, geographic information systems and their development signals a need for the introduction of intra-regional training. There is considerable disparity in numbers of trained technical and professional staff, facilities, basic access to data, levels of application of the technology, and acceptance of the technology. The entire Pacific region has only a few staff with graduate-level qualifications in remote sensing, GIS, or computer-aided cartography. Some Pacific Islanders have had advanced image analysis and geographic information systems training but, on return to their home countries, have faced major constraints in the lack of comparable equipment and facilities available for use.
- The smaller countries require assistance in setting up a basic air-photo archive with minimal analysis equipment. Few of the countries surveyed have any organised archive of satellite data even in photographic form.
- In countries with well-developed cartographic capabilities, there are incipient problems with maintenance of aging equipment. Mapping Divisions often have difficulty in convincing budget and aid controllers of the need to maintain and update plant and equipment as an investment for the future. Everyone uses maps but few stop to ask how they are made!
- Where land and sea resource surveys are conducted and/or systems introduced there is continuing reliance on outside expertise. This reinforces continued dependence in an area where nationals should have an inherent advantage — knowledge of their own countries. Purchase of overseas expertise to carry out major inventory or monitoring projects also transfers scarce national and/or aid funds away from the Pacific countries.
- If countries and agencies were more self-reliant in the use of remote sensing, resources monitoring could be done routinely at regular and shorter intervals. This is more cost-effective and efficient and would ensure that information was up to date. It would reduce the need for major reviews at 5–7 year intervals.
- Unless positive remedial effort is made soon the gap will become larger and increasingly difficult to overcome as the technology develops further in the 1990s. Dependence on external assistance, a misdirection of scarce national resources, will become chronic.
- Remedial action must include increased opportunities for technical training of both graduate and non-graduate staff. Only if the general pool of staff with technical skills is increased at all levels will the current 'stop–go' technology transfer cycle be halted. In addition, there is benefit in increased exposure to remote sensing and geographic analysis in the curricula of the regional tertiary education institutions. It also presents opportunities for regional technical cooperation and development between the Pacific countries.

Remote sensing in regional agencies

Specialised agencies which have expressed interest in and, in some cases, see a positive benefit resulting from extension of the technology include the South Pacific Forum Fisheries Agency (FFA), the United Nations Food and Agriculture Organization (FAO), the UNDP/ESCAP Regional Remote Sensing Program (RRSP), the South Pacific Applied Geoscience Commission (SOPAC), the South Pacific Commission (SPC), and the South Pacific Regional Environment Program (SPREP).

Other bodies with declared interest in application of the technology include geographic information system and image-processing organisations and companies in Australia, France and New Zealand.

SOPAC investigated the use of remote sensing and GIS to support annual work programs. SOPAC applications are limited to geological and coastal (shallow water) engineering and geological resource mapping. The Commission conducts a comprehensive training scheme which includes training in survey techniques, air-photo interpretation and cartography.

ESCAP has (June 1990) completed a two-year subprogram of the RRSP in the Pacific. FAO and UN–DTCD, while they have no direct GIS or remote sensing presence in the Pacific, are associated with ESCAP in the execution of the program.

UNESCO has supported remote sensing workshops in the region through their ROST/SEA office in the past (1986) but has had no recent activities. The Forum Fisheries Agency (FFA) and the SPC Coastal Fisheries Program have shown interest in remote sensing and, more recently, GIS (Preston 1991). They have no programs in place.

SPC and SPREP activities have been closely interlinked until 1990 when it was agreed that SPREP should become a distinct entity. The SPC/EC consultancy recommended that both bodies should continue to cooperate in the area of remote sensing and GIS applications. It is likely that a small image processing facility will be acquired to support SPC fisheries and agricultural programs in particular. SPREP is proceeding to develop a project to establish a Global Resource Information Database (GRID) sub-regional node with UNEP and ADB donor support. While focusing on GIS training and technology transfer it will also provide small image processing capability to the organisation and selected island countries.

The SPC/EC consultants (Collotte and Meijere 1991), a UNEP/GEMS report (Claasen 1990) and findings of two regional workshops/working group meetings (ESCAP 1990, 1991) all recommended that any remote sensing and GIS technical cooperation and development program in the Pacific should focus on training, maintenance support, information exchange networking and applications research. There appears to be consensus that development of any large central facility would not be warranted as such facilities already exist in Australia, New Zealand and in the two French Territories of French Polynesia and New Caledonia.

Educational institutions

The University of the South Pacific (USP), Suva, Fiji, and Apia, Western Samoa, and the Papua New Guinea University of Technology (UNITECH), Lae, PNG, have both shown interest in remote sensing (primarily) and GIS applications. The University of Guam (UG) has recently introduced remote sensing as an undergraduate course option.

The Université Francaise du Pacifique (UFP) cooperates with both the IFREMER/French Polynesia Remote Sensing Centre in Tahiti, French Polynesia, and ORSTOM/LATICAL remote sensing laboratory in Noumea, New Caledonia, to offer training and university level courses in remote sensing.

USP is of particular interest in that it is a regional university operating through 11 countries of the SPREP region. It maintains two campuses (Suva, Fiji, and Apia, Western Samoa) and eight University Centres, one in each participating country. It supported the UNDP/ESCAP RRSP by providing office space and infrastructural support to the RRSP South Pacific sub-program. Currently, however, remote sensing is restricted to being taught as a component in geography courses.

The Department of Surveying and Land Studies of the PNG University of Technology (UNITECH) offers degree courses in Surveying, Cartography and Land Management. Students in these courses must take a minimum of 60 hours instruction and practical work in remote sensing and GIS topics. UNITECH now has seven staff members and a comprehensive array of facilities to support its teaching and research program. It would be an important component in any regional research and training program.

The University of Queensland, James Cook University of North Queensland (JCU), and the Royal Melbourne Institute of Technology (RMIT) in Australia, and the University of Auckland (UA), New Zealand, have indicated interest in providing training in the Pacific.

The Australian Key Centre for Land Information Studies (AKCLIS), a joint program of the University of Queensland, Queensland University of Technology and the Queensland State Government, has already conducted training in remote sensing applications for land and sea resource survey in association with RRSP and SOPAC. The centre has a Memorandum of Understanding with USP's Institute of Natural Resources to support joint research, education and training in GIS and remote sensing in the region.

The Remote Sensing Centre at RMIT is conducting applied research and consulting in Tonga. It is also interested in expanding its activities elsewhere in the Pacific.

JCU is cooperating with researchers at UNITECH and USP in applied remote sensing research.

Multilateral donor organisations

There has been little direct multilateral donor support

for geographic information and remote sensing technology transfer and training in the Pacific.

A limited contribution was made by the United Nations Development Program (UNDP) through the ESCAP-executed RRSP, South Pacific sub-program (RAS/86/141). UNDP also supports programs which use, or could potentially use, geographic survey and assessment processes.

The situation is, however, fluid. As a result of the RRSP sub-program, a project formulation proposal for the 1992–97 United Nations Indicative Planning Figure (IPF) cycle was submitted to ESCAP to seek UNDP and other support for a Pacific Sub-regional project to effect GIS and remote sensing training for Pacific countries. This proposal does not appear to have been included in the next cycle.

A similar proposal was made by the SPC/EC team in 1990 and was endorsed at the ESCAP/AIDAB Suva working group meeting in April 1991.

The Asian Development Bank (ADB) is active in supporting national agricultural, environmental and land-use assessment projects in the sub-region either through direct technical grants and/or development loans. Some of these, notably in Western Samoa, have included GIS installations.

The ADB has expressed interest in a UNEP/SPREP GRID project proposal for a Pacific regional GIS training and technical support program to be operated through SPREP. UNEP has already assigned seed funding and a decision by ADB is expected in the near future.

Regional bilateral donors

Bilateral donors and programs tend to support discrete resource survey activities and technology transfer projects. Any training is usually part, and not sustained beyond the life, of any specific project. Sustained research, education and training programs focused on GIS and remote sensing have received little direct attention. Australia, France, New Zealand and the United Kingdom have supported inventory and GIS-styled database projects in the Pacific. AIDAB particularly has indicated support in principle for the development of GIS in the Pacific countries (ESCAP 1990a, 1991). It has supported development of resource information system projects in PNG, Vanuatu and Solomon Islands.

New Zealand is assisting the Cook Islands in developing a land-use information system.

Donor agencies from these and other developed countries have supported or expressed support for such initiatives. These include the Australian International Development Assistance Bureau, the European Community, and the French and New Zealand aid agencies.

The Japanese International Co-operation Agency (JICA), while active in the Pacific area, has not supported resource mapping or assessment projects in the Pacific to date. Japan, however, does take a strong interest in the Asia–Pacific RRSP and in UNEP/GRID.

AIDAB signalled strong interest in regional cooperation by jointly sponsoring a working group meeting of specialist agencies and Pacific countries early in March 1991. This follows concern at the possible proliferation and duplication of development-related inventory projects funded by various multi- and bilateral donor agencies and implemented through various ministries and/or regional organisations. The meeting considered the coordination of efforts to introduce the technology in the sub-region.

The larger countries of the Pacific, together with AIDAB, ESCAP, UNDP and other organisations, see a need to coordinate the management of these databases, some in GIS form, at the national level. This should ensure some degree of compatibility in data collection protocols, database components and system compatibility, to facilitate data exchange and application between ministries.

The importance of coordination and data exchange compatibility is acknowledged in the UNEP GRID and SPREP action plans. The need is recognised by other specialist Pacific agencies such as the South Pacific Applied Geoscience Commission (SOPAC), Forum Fisheries Agency (FFA), and South Pacific Commission (SPC) at sub-regional and regional levels. The SPREP/UNEP initiative in the region could act as catalyst in this necessary process.

Other organisations

The area of resources management and environmental planning in the Pacific is of considerable interest to a number of multi-national non-government organisations. The International Union for the Conservation of Nature (IUCN) is currently implementing the development of a national environmental inventory and plan for the Fiji Government with ADB funding. The Association of South Pacific Environmental Institutions (ASPEI), associated with SPREP, has a general and specific interest in environmental monitoring, as does Greenpeace New Zealand.

The Marine Research Foundation, Tonga, has proposed an electronic atlas for resource management and project planning in Pacific islands using a low-cost computer system.

Research and Development

Pacific island countries

The principal centres for remote sensing oriented research and development located wholly within the Pacific Islands are IFREMER SPT, Papeete, Tahiti; ORSTOM/LATICAL, Noumea, New Caledonia, and UNITECH, Lae, PNG. Environmental physics researchers at USP, Suva, Fiji, are also new entrants to the field. The history of such research is comparatively new but has begun to have a significant impact in the Pacific Island Countries as the results are circulated. The pilot studies have so far been limited to a few locations in the island countries, and the findings need to be tested in other areas.

IFREMER and ORSTOM are strongly supported by French funding. The UNITECH efforts have recently received multilateral and private donor assistance with development and organised research at a relatively early but not insignificant stage.

Activities to date have focused on coastal littoral, shallow water bathymetry and forestry applications. There have been good results in the mapping of reef biophysical zones for habitat analyses, mangrove and forest cover mapping, terrain analyses for flood and avalanche risk mapping, and post cyclonic disaster assessment.

Australia and New Zealand

Australia and New Zealand are well-established users of remote sensing and a significant research and applications infrastructure is in place. Both countries are involved in the fundamental application of remote sensing to the maintenance and improvement of global habitability, monitoring of the global environment and ecosystems, and studying global earth processes. Of great significance to the Pacific has been the dominance of primary resources to these countries which has fostered a remarkably strong remote sensing applications sector.

Australia has the only non-environmental (i.e. meteorological) satellite receiving station in the region at Alice Springs (the Australian Centre for Remote Sensing or ACRES). It is significant to the Pacific because it acquires data over most of the island of New Guinea.

The Australian research and development industry has successfully developed airborne scanner systems, a host of information analysis programs and sound applications research and operations. It is internationally recognised for remote sensing research, education and training, the latter being particularly respected in the Asia–Pacific Region. It has not exploited these advantages to full effect either commercially or as an aid to development in its natural geographic sphere of influence (Australian Space Board 1989).

Of particular note to the Pacific are applications in:

- integrated management (e.g. management of catchment areas, water resources, agriculture, forest and environment assessment and monitoring, transport, settlement monitoring);
- mineral exploration;
- fishing industry and other maritime users which could benefit commercially from ocean temperature and condition data derived from the NOAA AVHRR data;
- coastal, coral reef and continental-shelf shallow water reconnaissance mapping as developed and applied on Australia's Great Barrier Reef;
- natural disaster monitoring; and
- cash crop quality, quantity and distribution assessment.

Australia therefore could offer significant services to increase the user base and improve user services in the Pacific particularly in the area of major project management, infrastructure design, integrated land information systems design, applications research, bureau services for mapping, cartography and image production, maintenance support systems, and education and training.

Agencies and institutions with particularly relevant experience in remote sensing and which have already developed some contacts with the Pacific Island Countries include a number of CSIRO Divisions, the Australian Institute of Marine Science (AIMS), Great Barrier Reef Marine Park Authority (GBRMPA), Australian Surveying and Land Information Group (AUSLIG), and a number of state agencies (NSW Department of Agriculture, Queensland Department of Lands and Department of Primary Industries).

Australian universities with Pacific links and active in resources mapping using remote sensing include the Australian National University (ANU), University of Queensland (UQ), Griffith University and the Queensland University of Technology (QUT),[6] the James Cook University of North Queensland (JCU), and the Royal Melbourne Institute of Technology (RMIT).

There are, of course, a number of commercial firms which also offer services in this area. Space prohibits further listing.

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[6] These three institutions together with the Queensland Department of Lands co-established the Australian Key Centre for Land Information Studies (AKCLIS).

New Zealand Most of the comments referring to Australia are also true of New Zealand. An added factor is the long association of New Zealand resource survey and mapping agencies, principally the Departments of Scientific and Industrial Resources (DSIR) and Survey and Land Information (DOSLI), with the Pacific Island Countries (particularly the Cook Islands, Fiji, Nuie, Solomon Islands, Tonga, Tokelau and Western Samoa). New Zealand agencies archive a vast amount of land resource information, mainly soils data, for these countries. They have a special affinity for island conditions and, because of their smaller size, are well accepted by them.

Apart from the above agencies, the University of Auckland (Auckland) and Massey University (Palmerston North) provide training and education and carry out research in applied geographic information technology.

Opportunities for research and development

The foundation for enhancing the role of remote sensing is quite strong. In addition to the work of IFREMER, ORSTOM, SOPAC and Australian and New Zealand some countries, particularly Fiji and Papua New Guinea, have made use of photographic remote sensing in the past. Notable examples are the land-use planning sections of primary industry agencies, which have a long history of using air-photo interpretation to assess and monitor land use. Pacific countries, however, feel that there is more benefit to be obtained from the various techniques developed over the past few years, particularly satellite-based sensing.[7]

Opportunities exist for collaborative research into a number of phenomena useful to various sectors. In the marine and coastal sector:

- *Sea surface temperature mapping for the location of tuna fishing areas.* Institutions working in this area include ORSTOM/LATICAL, IFREMER/SPT, CSIRO Divisions of Fisheries, Oceanography, and Water Resources, SACRS and AIMS. Institutions/agencies which would immediately benefit from further research and proven applications in this area include the South Pacific Commission Tuna and Billfish Program.
- *Mapping of mangrove areas and types for the assessment of impact, fish nursery habitat and compensation for the loss of fishing rights following foreshore reclamation.* Organisations doing research include ORSTOM/LATICAL, AIMS, JCU, SOPAC, UNITECH, SACRS and the beneficiaries are all Pacific island countries, SPC Nearshore Fisheries Project and SPREP.
- *Changes in rivers and sedimentation patterns to predict effects on freshwater and marine shellfish productivity.*[8] Some sediment analysis research is being done by AIMS and CSIRO Division of Water Resources. The beneficiaries are Pacific island countries' fisheries agencies.
- *Locating reef areas suitable for aquaculture development, particularly for clam grow-out areas, and seaweed-farming.* Research is being conducted by AIMS, AUSLIG, JCU, ORSTOM/LATICAL, IFREMER/SPT, GBRMPA, SOPAC, UNITECH, SACRS, and SPC Nearshore Fisheries. The research will benefit PIC fisheries and primary industry agencies and SPC nearshore fisheries.
- *Shallow water bathymetry to assist in defining fishing rights areas and also navigation of fishing vessels.* Research is being conducted by AUSLIG, AKCLIS, JCU, IFREMER/SPT, UNITECH (PNG), USP (Fiji), and SACRS. The potential beneficiaries are all Pacific island countries fisheries agencies, Pacific island countries' land and sea ownership delineation agencies (e.g. NLTB Fiji, Lands Commission PNG), lands survey and hydrographic agencies.
- *New fishing ground location (e.g. new seamounts, which are generally more productive than the surrounding ocean and which may be located through localised plankton concentrations).* Research is being conducted by ORSTOM/LATICAL, IFREMER/SPT, AIMS and CSIRO Divisions of Oceanography and Fisheries. This research will benefit FFA and SPC (Pelagic and Nearshore Fisheries Programs).

In the agricultural sector, land-use mapping input into geographical information systems and monitoring are two potential primary applications of satellite imagery analysis.

Land-use and land-capability maps are normally obtained through conventional air-photo interpretation and field surveys. Although this is usually the best approach it is both expensive and time-

[7]Remote sensing seminar for Decision Makers, 30 March 1990. Fiji Department of Lands and Survey, sponsored by UN–ESCAP and AIDAB. Attended by 40 senior representatives of 25 government resource, planning and statistical agencies.

[8]Freshwater clam or Kai is an important shellfish caught mainly in Fiji and a mainstay of village economies (Government of Fiji 1990).

consuming, especially in agencies having limited resources. Satellite remote sensing techniques present by far the best complementary role, particularly if all that is needed is an incremental updating of the original accurate maps.

For countries with no extensive automatic processing facilities, the optimum solution would be visual interpretation of satellite data. Most countries cannot hope to get a good vegetation or land-use pattern map of the whole country updated regularly using conventional methods. Usually it can take up to ten years for such intensive work. By the time the work is finished a new map is needed because so much has changed again.

Applications for land-resource management survey using satellite imagery include:

- *Land use changes and patterns.* Change analysis is a proven technique not often used in Pacific island countries. There is scope for research into crop and land-use signature patterns or identification keys. AKCLIS, ORSTOM/LATICAL, DSIR (NZ) Land Resources Division and CSIRO Tropical Crops and Pastures are all active in research. The beneficiaries are SPC agriculture-rural development programs, SPREP and national primary industry agencies.

- *Forest inventory.* Active research (again a proven technique but more research is needed on wet tropic forest analyses) is being done by AKCLIS, JCU, CSIRO Division of Tropical Crops and Pastures, BHP (AIDAB/Philippines Project), NSW Department of Agriculture, NSW Forestry, Queensland Forestry, SACRS and NZ-DSIR Land Resources. National forestry agencies are potential beneficiaries.

- *Monitoring successional changes and fire effects.* This is a proven technique used by most forestry agencies in Australia and New Zealand but not in use in the Pacific even with air-photo interpretation. Research in this area is being carried out by AKCLIS, SACRS, CSIRO Water Resources, SACRS and NZ-DSIR Land Resources. The beneficiaries are national forestry and environment planning agencies.

- *Land erosion mapping and monitoring.* These procedures are used in arid areas but are not extended to monsoon, moist or wet tropics areas to any great degree. JCU, UNITECH (PNG), SACRS, AKCLIS, and ORSTOM/LATICAL are all active in research NZ-DSIR Land Resources. The potential beneficiaries are land use, forestry and primary industries agencies in the high island countries of the Pacific especially Fiji, PNG, Solomon Islands, Vanuatu, New Caledonia, and SPREP.

- *Sediment load analysis for erosion monitoring.* Research is being done by CSIRO Divisions of Water Resources and Oceanography, AIMS and possibly some state agencies responsible for water management and sewage control. The beneficiaries are the same as those for land erosion mapping.

- *Crop yield monitoring.* Agriculture agencies Australia-wide (particularly in NSW and Queensland), SACRS, two CSIRO Divisions — Water Resources, and Tropical Crops and Pastures — and USP School of Pure and Applied Sciences are all doing research. The potential beneficiaries are national planning and forecasting agencies, and primary industries agencies.

- *Watersheds, agricultural census and specific agricultural project monitoring.* Research is being conducted by agriculture and forestry agencies in Australia especially NSW and Queensland, AKCLIS, SACRS and the Commonwealth Bureau of Rural Resources. The potential beneficiaries are Pacific island countries primary industry departments, rural development, and forestry agencies, SPC Agriculture and rural development programs and SPREP.

As can be seen, there is considerable scope for collaborative applications research involving Australian, Pacific island country, regional organisations, French (French Polynesian and New Caledonian) and New Zealand agencies.

Scope for ACIAR

In analysing the current and projected use of remote sensing it is probable that the trend will be to establish small national and regional image analysis facilities. The individual user units will be linked through a technical cooperation and development network to existing facilities in French Polynesia, New Caledonia and to suppliers in Australia and New Zealand. There will be no justification for a major regional remote sensing support facility such as proposed at SPC. This conclusion is confirmed by recent studies carried out on behalf of SPC (Collotte and Meijere 1991), UNEP and SPREP (Claasen 1990), and ESCAP/AIDAB (Mau 1991), as well as the views expressed to and through ESCAP RRSP programs and meetings (ESCAP 1990a, b, 1991).

The consensus seems to be that activities already in train and the number of existing and increasing facilities and available services do not warrant the establishment of another major regional facility at SPC or elsewhere. The operational requirements of larger and intermediate countries will be met through acquisition of their own facilities. The needs of smaller countries

can be satisfied by existing regional organisations who have already or will acquire their own facilities. Major services can be supplied from Australian, French or New Zealand suppliers provided funding can be found.

With respect to facilities, therefore, it is suggested that ACIAR support the recommendations of these studies to establish a service network program. This would assist Pacific nations and regional organisations in developing RS/GIS applications to support national economic development planning, environmental management and regional cooperation and development. The focus of the program will be to facilitate use of existing services in project development and implementation support, assist users to access services through the network for internal projects, and enhance national and even individual agency facilities.

A constructive role for ACIAR would be to exercise its specific mandate to foster joint Australia–Pacific applications research to extend applied remote sensing in the Pacific. It is essential that such support should focus on applications in practical areas where efficiency in data acquisition is a vital factor. To qualify for support the proposed research projects should meet the following criteria.

- Aim to prove the utility of marine and coastal remote sensing applications in Pacific environments and resource use patterns. Projects included under this grouping would either foster new research, or apply research results validated elsewhere to Pacific conditions, and where applicable, incorporate a requirement to apply a benefit–cost assessment of the technique(s) compared with other techniques.
- Promote the adoption and integration of applied remote sensing techniques to enhance and improve the cost-effectiveness or efficiency of existing operational programs. Projects included under this operational integration grouping would examine inventory and monitoring project or project component proposals and assess whether scope exists for 'top-up' funding to incorporate an applied remote sensing component in the project (an example would be the development of the baitfish site atlas within the ACIAR/CSIRO baitfish project[9]). The research component would evaluate the traditional and remote sensing survey techniques used in the project including the assessment of time, costs, viability of technique and time/cost savings made in production of maps, atlases, etc.
- Fund large-area resource inventory surveys to provide necessary information for land or sea resource-use planning and management. These projects could encompass reconnaissance level biophysical and indicative bathymetry of reefs and lagoons of the atoll states, reef habitat mapping for giant clams, trochus, etc. Such support could be extended to joint research proposed by national agencies, universities, regional organisations in conjunction with Australian agencies and institutions, and full survey assistance to regional agencies — SPC inshore fisheries program; SPREP, SPC agriculture program, assistance with PAIS (provide spatial data links), national agencies.

A good candidate project is to provide assistance to the South Pacific Commission's Nearshore Fisheries program. Of all the regional activities this program has a continuing need for reconnaissance-level surveys of nearshore and coastal fisheries habitat. The techniques to assess shellfish (trochus, giant clam, black-lip pearl) habitat have been successfully developed for French Polynesian, New Caledonian and, generally, Australian conditions. There are two questions.

- Can the techniques be generally extrapolated to all the South Pacific Island Countries? Experience to date suggests it is viable and would allow Pacific island countries to survey their potential for harvesting and/or mariculture industries of the various species.
- If the technique is valid and reliable, can it be incorporated cost-effectively and efficiently into an operation regional support program (e.g. SPC Nearshore Fisheries)?

A project to address these questions would appear worthy of support as it meets a practical operational requirement, i.e. to provide information useful for stock assessment and planning, and evaluate the techniques.

Joint research opportunities

There is a bewildering number of potential remote sensing (applications) research participants in the Pacific. They include national governments, individual government agencies in each country, regional organisations and international agencies. The potential for duplication of research and even operational activities is high. Coordination is therefore one justification for a regional applied remote sensing (and GIS) technical cooperation and development network to operate through one of the existing regional bodies. It is suggested that ACIAR should, in principle, actively encourage the development of such a network. In practical terms, the most direct and effective course is to build on existing linkages

[9] ACIAR/CSIRO Baitfish Project: CSIRO Division of Fisheries, Cleveland, Qld.

between Australian and Pacific institutions. Some of these [e.g. SPC/GBRMPA (this consultancy) and CSIRO/SPC (Baitfish Project)] are already supported by ACIAR.

The nature of the existing linkages varies. Some — JCU/UNITECH, AKCLIS/UN-RRSP and Fiji, and RMIT/Tonga — are recent. Others — Fiji/AUSLIG, SACRS/various country agencies, CSIRO DWR (UN-RRSP), and CSIRO TC&P (PNG) are historical and continuing. They are made more complex by the growing tripartite research between Australia, New Zealand and the two French Territorial institutions (e.g. NZ–DSIR Land Resources/AKCLIS, IFREMER and ORSTOM. The cooperation is encouraging but there is need to open communications with other partners who may have an interest in the research topic.

Details of various institutions with current interests in remote sensing in the Pacific are given above and in Appendix 1. They are summarised in Table 1.

Table 1. Summary of institutions and organisations with remote sensing interests

Acronym	Full title	Indicative links
Australian institutions		
AKCLIS	Australian Key Centre for Land Information Studies	University of Queensland, Griffith University, Queensland University of Technology, Qld Dept of Lands (SUNMAP), James Cook University, Northern Territory University.
RMIT	Royal Melbourne Institute of Technology	Victoria University of Technology.
JCU	James Cook University of North Queensland	AKCLIS, AIMS, GBRMPA.
CSIRO	Division of Fisheries	
	Division of Water Resources	AUSLIG, GBRMPA, AIMS, JCU, AKCLIS
	Division of Tropical Crops and Pastures	Qld Forestry Dept; Qld Dept of Primary Industry
AIMS	Australian Institute of Marine Science	JCU, GBRMPA.
GBRMPA	Great Barrier Reef Marine Park Authority	AIMS, JCU, AKCLIS, AUSLIG.
SACRS	South Australia Centre for Remote Sensing	GBRMPA
AUSLIG	Australian Survey and Land Information Group	AKCLIS, SUNMAP, CSIRO DWR, GBRMPA
Developing countries of the South Pacific		
Papua New Guinea, Fiji, Solomon Islands, Western Samoa, French Polynesia, New Caledonia, Vanuatu, Guam, Tonga, Federated States of Micronesia, Kiribati, American Samoa, Marshall Islands, Cook Islands, Commonwealth of the North Marianas, Palau, Wallis and Futuna[a], Tuvalu, Nauru[a], Nuie[a], Tokelau[a], Pitcairn[a]		
Regional agency(ies) programs		
SPC	South Pacific Commission	CSIRO Fisheries, AIMS, JCU
	Fisheries	
	Agriculture	
SPREP	South Pacific Regional Environment Program	ANPWS
SOPAC	South Pacific Applied Geosciences Commission	BMR, BRR-NRIC
UN	ESCAP Regional Remote Sensing Program	
	FAO Food and Agriculture Organization	
Other developed country programs		
NZ DSIR	Dept of Scientific and Industrial Research[b]	
LATICAL	Laboratoire de Traitement d'Images Caledonien (ORSTOM)	
SPT	Station Polynesienne de Teledectection (IFREMER)	
Universities in Pacific Island countries		
UNITECH	PNG University of Technology	JCU
USP	University of the South Pacific	UQ–AKCLIS, JCU

[a] Denotes no immediate need for technology
[b] Currently under review

Indicative Support Costs

An analysis of costs without any specific project in mind can, at best, be indicative only. A full regional site comparison project could require as much as $250 000–350 000. Top-up funding to incorporate the use and evaluation of remote sensing techniques within a larger project would be much less as field work, logistics and production costs would be covered already. The components outlined below may assist in giving some cost indications.

A remote sensing techniques evaluation project

The cost assessment draws largely on a remote sensing evaluation project proposed by FAO for the Pacific some years ago. The project was not funded by any donors but it contained elements of items discussed above. Some modifications have been made. A summary is presented in Tables 2 and 3.

A project of this nature would take up to 18 months with a 2–3 month ground survey and substantial on-the-job and post-project training components. It would need the facilities of a well-equipped image analysis and output laboratory for a total of about 4–5 person-months. In the Pacific this would mean using the SPT in Papeete, LATICAL in Noumea, NZ–DSIR Land Resources in Palmerston North, or any relevant Australian institutions.

Example of a basic resource inventory project

An Australian example of an operational project is the mapping of the over 2500 reefs of the 340 000 square kilometres Great Barrier Reef region and Marine Park at 1:250 000 with biophysical parameter products at 1:50 000. The work was carried out by the Australian Surveying and Land Information Group (AUSLIG) for the Great Barrier Reef Marine Park Authority (GBRMPA) using analysis techniques specifically developed for shallow water mapping by the CSIRO Division of Water Resources (DWR).[10] Details of this work have been extensively reported (Jupp et al. 1985, Claasen et al. 1986).

[10]Previously the CSIRO Division of Water and Land Resources

Table 2. Example of a major applied remote sensing evaluation project

Objective:	Produce a set of thematic maps of immediate use to forestry, fisheries and agriculture project implementation and monitoring for selected zones representative of South Pacific conditions.
Conditions:	The map products must be obtained from low-cost technology, therefore the base should be high-resolution satellite data analysis. Study areas should incorporate examples of the main island types found in the region, i.e., atolls (e.g. Kiribati, Tuvalu), high islands (Rarotonga, Cook Islands), lagoon under tropical regime (e.g. Fiji), and lagoon under equatorial conditions (e.g. Solomon Islands). One study site to be selected in each of the four island types.
Output Products	1. Photo base map at 1:100 000 scale for each site. • Products to consist of satellite enhanced colour composite prints on which infrastructure, habitat, surface water bodies and indicative satellite bathymetric depth zones (3–5 classes, 0–20 metres) are printed. Optimum size of study areas to be 20 × 20 km for high islands and atoll, 40 × 40 km for lagoon areas. 2. Thematic maps • Land-use map at 1:50 000 on 2 selected test sites of 20 × 20 km with emphasis on agriculture and forestry resources including mangroves; • Coastal and submerged land cover map at 1:50 000 with themes applicable to inland and marine fisheries (classes of different coral and sand cover, potential aquaculture sites, etc.). • Ecological constraints map at 1:25 000—over sub-areas of 10 × 10 km for each of representative sites of coastal map. Highlight ecological impact of development of important activities (tourism, fisheries, intensive agriculture, aquaculture, mining, etc.). 3. Technical report in which techniques are evaluated for South Pacific conditions including benefit–cost analysis. Well and simply presented so it can be used as a training and implementation handbook. 4. Training program on the remote sensing techniques applied to natural resource inventories in the Pacific Islands based on the project (e.g. 4 officers from 4 countries).

Source: D. Lantieri 1986.

Table 3. Indicative budget

A budget for the project suggested in Table 2, adjusted to 1990 figures, would look something like the following. All values are in US$.

Consultancy @ 15.5 person months[a]	145 000
Travel (preparation, ground survey training (including travel for trainees), presentation of results to participating country)	56 000
Subcontract image processing and map production	42 000
Logistics (ground, marine, aerial survey)	15 000
Supplies and material (satellite imagery, colour prints, air photos, maps, etc.)	23 500
Total	281 500

[a] Assumes full consulting cost recovery factor of ×2.6 monthly salary of $3600/month

The project brief required the analysis of Landsat MSS (80-metre resolution) images to produce thematic image-map products at 1:50 000 and one colour composite product per image at 1:250 000. The products included:

- biophysical reef zone image maps;
- indicative bathymetry of reef lagoons and shoals image maps;
- indicative reef shape and high/low energy area image maps.

The project produced the required image-maps over an 18-month period for some $A250 000, excluding staff salary costs. The image analysis equipment and software are now readily available as microcomputer workstation packages. The end-map techniques used by AUSLIG at that time were manual and time-consuming and could be much improved with state-of-the-art computer-aided mapping systems and plotters.

Allowing for cost increases, and including staff time, the 1991 cost for this project (in $A) is estimated and summarised at the top of the next column. The type of approach and indicative cost would apply to a similar inventory and reconnaissance mapping project of the shallow water resources of Kiribati or Tuvalu.

It should be noted that the costs given are not indicative if the project was done on a full consultancy basis. This would attract commercial costing rates and salary costs of 2.0 to 2.6 times those shown. Setting up the laboratory was not costed as AUSLIG already had the necessary equipment.

• **Cost of image map production**		
1984–85 (per km^2)	$0.73	
1990–91 (est. per km^2)	$1.29	
Total estimated cost for 340 000 km^2 (1990)		$438 600
• Staff component (3× 18 months)		
1990–91 cost (per km^2)	$0.44	$148 500
Total estimated cost for 340 000 km^2 (1990)		$58 710

A valid base for comparison is the cost of alternative techniques to acquire the same basic reconnaissance level data. AUSLIG estimated that acquisition of the same data would take decades and cost $10–20 million using conventional ship survey and soundings techniques. The experience showed that the use of satellite remote sensing could:

- provide reconnaissance-level data useful and necessary for regional planning purposes; and
- permit coverage of the area to a degree which would not be contemplated for conventional surface surveys at all, given the cost of the latter.

Top-up assistance to inventory projects

If assistance was extended to existing projects to incorporate a remote sensing component it would only have to cover the cost of acquiring remotely sensed data, a training component if necessary, a design–implementation time–cost component, an analysis component, an evaluation (including accuracy, costs and benefits) component and a marginal added cost in reports and/or publications.

It is difficult to be more precise without having a defined project as interpretation costs will vary considerably between the different data types and the analysis techniques. A median interpretation cost could be around $ 0.44 per km^2. To this would need to be added other incidentals such as cost of hardware and software systems (if these are to be provided), field logistics costs, evaluation and reporting costs.

The key is to suit the data type to the end objective. If very high resolution is required (e.g. individual forest species recognition) then the choice would be aerial photography (preferably colour in the tropics). If depth of penetration in marine areas is required then one might select the Thematic Mapper data as it has the greatest spectral resolution.

A project to support marine shellfish habitat reconnaissance mapping as suggested above would be a good example of technology (or technique) transfer to operational conditions.

Table 4 summarises the acquisition cost for different types of remotely sensed data.

Table 4. Remote sensing data costs and attributes

Sensor	Working scale	Cost/scene	Cost/km^2	Scene cover (km)	Resolution	Frequency
NOAA–AVHRR	1:1 500 000	125 (CCT)	–	2700×2700	1 km	8 hours
LANDSAT MSS	1:100–250 000	960 (CCT)	0.03	185×185	80 m	16 days
		420 (print)	0.01			
LANDSAT–TM	1:50–100 000	4500 (CCT)	0.13	185×185	30 m	16 days
		700 (print)	0.02			
SPOT–XS	1:50–100 000	3100 (CCT)	0.86	60×60	20 m	1–5 days
		2980 (print)	0.83			
SPOT–PA	1:25–50 000	3815 (CCT)	1.06	60×60	10 m	1–5 days
		3295 (print)	0.92			
Air-photo (existing)	1:50 000	20 (print)	0.20	10×10	50 cm	5–10 years
Air-photo (existing)	1:25 000	20 (print)	0.80	5×5	25 cm	5–10 years
Airborne scanner	1:1–50 000	Function of location but c. $200–500k (CCT)	69.00	variable with flying height	1–20 m	as required

Notes: NOAA AVHRR Advanced Very High Resolution Scanner (*4 bands); LANDSAT MSS Multispectral Scanner (×4 bands); LANDSAT TM Thematic Mapper (×7 bands); SPOT XS Multispectral Scanner (×3 bands); SPOT PA Panchromatic (×1 band = black and white); and CCT = Computer Compatible Tape

Conclusions

Natural resource management issues — an overview

The major issues in Pacific resource and environmental planning include:

- inconsistent delivery to decision makers and planners of timely, acceptably accurate and appropriate information on the quality, quantity and distribution of resources;
- scarcity of integrated data on natural resources and the environment in a form which clearly conveys the salient facts to decision makers and planners.

These problems are caused by:

- scarce resources—small countries have a small natural and human resource base with many demands, too many projects and activities in each country;
- shortage of staff trained in manual and computer-assisted processes to interpret air photography and satellite data and handle geographically coded data and information;
- poor infrastructural capacity to absorb remote sensing technology; and
- lack of awareness of benefits and cost-effectiveness to management of remote sensing and geographic information systems.

There is extensive interest in, and a growing intra-national and intra-regional trend towards the acquisition and application of geographic information and supporting image analysis systems technology. The trend is supported by a global trend towards more powerful and reliable software and hardware at reasonable cost.

Current use of remote sensing

Current use of remote sensing is relatively restricted to a few applications. Most activities concern conventional interpretation of panchromatic aerial photography for cartographic, land-use planning, forestry and some fisheries purposes. Even these are not universally applied in all countries. Cost constraints significantly inhibit even the use of off-the-shelf photography for a number of departments in some countries.

There is therefore a reluctance to experiment with new uses and/or forms of remotely sensed data (e.g.

aerial photography, satellite imagery) analysis as they are perceived to be more expensive and not useful to Pacific conditions. Representatives of all countries acknowledge a need to demonstrate and publicise proven applications of remote sensing appropriate to Pacific user needs.[11]

In essence there are three areas which should be addressed if the Pacific Island Countries are to become more self-reliant in natural resource data acquisition and management:

i) technical cooperation and coordination between the countries of the region to ensure the orderly and effective transfer of the technology to user groups;

ii) education and training opportunities within each country and within the region; and

iii) applications research, to prove the technology within the region, and practical assistance in the development and in-country implementation of applications projects.

There is therefore scope for programs which will:

- promote and coordinate technical cooperation and development of remote sensing and GIS applications projects and project support between countries;
- provide access to basic and specialised training in remote sensing and geographic information analysis techniques and technology; and
- provide cooperative mechanisms to strengthen and/or develop sub-regional and national capabilities to monitor and assess natural resources and environment through practical applications research.

Dedicated regional remote sensing facility

The evidence of increasing interest in, and growing application of, higher technological forms of remote sensing in the Pacific does not necessarily justify establishment of a regional centralised support facility.

The evidence suggests that the pattern of development will consist of the installation of increasing numbers of microcomputer-based image analysis systems in the regional organisations and some national agencies. Some larger systems will be installed in Papua New Guinea and Fiji to join the IFREMER/SPT and ORSTOM/LATICAL systems already in the region. The owners of smaller systems will need to seek bureau services (for large projects, high quality map and/or image production) from time to time. These can be provided by existing facilities in the region or from Australian and New Zealand suppliers.

Recent studies (Collotte and Meijere 1990, Claasen 1990, Mau 1991) confirm the adequate supply of high-technology remote sensing equipment and services available in or adjacent to the region if required. The challenge is in making those services more accessible to the users and to ensure the end users can benefit from the technology. The cost of establishing, operating and maintaining an additional, fully equipped remote sensing and GIS centre would be prohibitive and superfluous.[12]

The real need is the development of a technical cooperation and development network which will allow the end users to make efficient and cost-effective use of the technology for their own purposes. This would need to be closely associated with regional and national efforts to increase survey, assessment and monitoring capabilities in specific sectors, e.g. environment, resource management agencies and institutions.

Such a technical cooperation network has been recommended by the above-mentioned studies. It also complements suggestions made in the Australian Remote Sensing Industry Strategy and Action Plan[13] to establish an Asia–Oceania Remote Sensing Centre Network as a '... mechanism for direct collaboration and mutual assistance in the solution of common problems'.

Research opportunities

The scope for applications research and technology transfer in tropical areas is considerable. The focus should, however, be on the practical application(s) not on remote sensing. The situation in the Pacific demands an increase in the numbers of resource specialists (e.g. land-use planners, foresters, environmentalists, fisheries managers) who can effectively use the technology to further their own assessment and monitoring needs.

[11] For example, the regular monitoring of resources to keep the increasing number of geographic information systems being installed in Pacific island countries up-to-date; or the extensive reconnaissance mapping of their vast marine shallow water resources.

[12] Such a centre would need to be funded for an indefinite period and be totally externally funded. Experience with other centres, e.g. RCSSM and RS in Nairobi, demonstrate that they face high capital and operating costs and considerable difficulty in achieving economic and institutional viability (Mau 1990).

[13] Report of the Remote Sensing Working Party to the Australian Space Board, Space Office, Department of Industry, Technology and Commerce, July 1989.

There is a need for projects and programs which foster the integration of technology at a level appropriate for operational work programs of regional and national resource and planning agencies. The focus of research should be to compare techniques and applications, prove or disprove their applicability in the Pacific context, and transfer those that are successful to the operational areas.

A suitable example project, as suggested earlier, would be to assist the South Pacific Commission's Nearshore Fisheries Program to meet a continuing need for reconnaissance-level surveys of nearshore and coastal fisheries habitat. The techniques to assess shellfish (trochus, giant clam, black-lip pearl) habitat have been successfully developed for French Polynesian, New Caledonian and, generally, Australian conditions. It would need to answer two questions—can the techniques be generally extrapolated to all the South Pacific Island Countries, and can it be incorporated cost-effectively and efficiently to meet a practical operational requirement, i.e. provide information useful for stock assessment and planning.

There is also need to develop common approaches, common definitions, standards and transferable methods. A good example is the project proposed by the University of Queensland Department of Geographical Sciences and the Queensland Department of Lands recently funded by AIDAB to produce design specifications for an air-photo interpretation manual for the South Pacific. The manual would use specific South Pacific examples to increase productivity of government officers involved in planning and natural resource management, provide training institutions in the Pacific countries with a teaching resource, and maximise previous and current sponsorship of AIDAB projects in the Pacific.

Potential costs

The Terms of Reference of this study requested an estimate of the costs to potential clients in using a regional facility. In essence, the cost to clients using a dedicated regional bureau facility would be of the same order as the cost of accessing those services from existing institutions and vendors in Australia, the French territories or New Zealand. The latter could arguably be less expensive as establishment costs would be spread over a larger clientele.

Costs are determined by the type of project, the type of services requested in relation to that project, and the desired end-product quality. It is difficult to be definite about costs without this information. The issue is discussed earlier, but costs could range from less than $10 000 to purchase satellite imagery with some basic enhancements, to more than $500 000 for major remote sensing based inventory projects aimed at producing information useful to a number of resource and planning sectors.

Input of Australian remote sensing institutions

Regardless of the eventual mechanism the opportunities for the involvement of Australian remote sensing research institutions is considerable.

A number of institutions have initiated joint research, training and educational initiatives. These include the Australian Key Centre for Land Information Studies (AKCLIS) with the UN–ESCAP RRSP, the University of the South Pacific (USP), SOPAC and the Government of Fiji; the James Cook University (JCU) with the PNG University of Technology, USP and SOPAC; and the Remote Sensing Centre of RMIT with the Government of Tonga. These initiatives should be encouraged and fostered.

A number of sector inventory and survey projects have been initiated which use remotely sensed data products. These include forestry and land use surveys, baitfish site research, etc., and involve elements of CSIRO (Divisions of Fisheries, Tropical Crops and Pastures, Water Resources). These could be expanded.

The recommendations made by the Remote Sensing Working party to the Australian Space Board are worthy of review particularly as they relate to international collaboration in the provision of '... a collaborative mechanism for identifying and solving common regional problems and to cement our market position in the region' and '... participation in global and regional environment and climate research, monitoring and management programs'.

There could be greater involvement by tropical environment, resource and marine institutions in applying their expertise to the problems and issues faced by the Pacific. The common constraint is the very real shortage of funds in the Pacific to initiate such research which must therefore be donor-funded. As the Australian institutions lack discretionary funding to consistently apply their undoubted knowledge to Pacific problems it is up to the regional agencies backed by applied research donor centres such as ACIAR to provide the linkages, coordination and, if necessary, the money.

Recommendations

In an assessment of this nature it is difficult to make any concrete recommendations regarding future action. There are however some suggestions which would assist in maintaining an adequate information base to assess possible activities which ACIAR might be asked to support or initiate.

ACIAR should:

- maintain a watching brief on Australian and Pacific proposals for regional cooperation in remote sensing applications research and technology transfer, and encourage and support in principle the development of any regional Technical Cooperation and Development Network program, as proposed by SPC/EC, UNEP/SPREP, AIDAB/ESCAP evaluations, as appropriate;
- continue to support active projects designed to incorporate remote sensing in operational programs such as the ACIAR/CSIRO Baitfish Project;
- investigate new joint proposals incorporating remote sensing in operational projects (e.g. the SPC Fisheries Habitat Mapping project suggested).

Acknowledgments

I wish to acknowledge the following people and institutions for their freely given help and time during the course of this consultancy.

- Dr Garry Preston and Mr Siliga Kofe of the South Pacific Commission for their commitment and administrative support in organising the mission and facilitating contact with SPC program staff.
- My colleagues for part of the mission, Mr Johan de Meijere, of ITC, The Netherlands, and Dr Pascal Collotte, Consultant, France, for stimulating discussions on, and important insights into, many aspects of resource data acquisition and handling.
- Mr Atanroi Baiteke, Secretary General of SPC, Mr Poloma Komiti, Deputy Director of Programs, SPC,

  Mr Vili Fuavao, Director of SPREP, for the time spent briefing me on the operations and information needs of their respective organisations.
- The many senior officers and staff of national agencies of Pacific Island Countries who use remotely sensed data and showed enthusiasm and support during my visits and in correspondence.
- The project leaders and staff of the various SPC, SPREP, SOPAC, USP and UNITECH programs who took time out to discuss their views and experiences related to the topic.
- My remote sensing and land and sea information management colleagues in Australian and New Zealand agencies and institutions who helped with information and comments—their combined contribution was invaluable.
- Particular thanks are given to ORSTOM and SPT and AIDAB and ESCAP who sponsored the Pix–Iles 90 Remote Sensing Workshop and the Working Group Meeting on remote sensing and geographic information systems in the Pacific, respectively, where much information was gleaned.
- Dr G. Rothschild, the Director of ACIAR, and Mr G. Kelleher, Chairman of the Great Barrier Reef Marine Park Authority, for the opportunity to undertake this study.

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Appendix 1. Status of Remote Sensing in the Pacific

Cook Islands

Local capacity and support

The Cook Islands Department of Survey (CI.DOS) acquires air photographs locally and receives back-up support from the New Zealand Department of Surveying and Land Information (DOSLI). Land resource management assistance is provided by the Division of Land Resources of the Department of Scientific and Industrial Research (DSIR).

Current use

Air-photo interpretation is used for land use and land capability mapping, erosion studies and stream pollution monitoring. Satellite data was used to map reef and lagoonal sediment substrate and biophysical habitat. The work was done with the help of both the South Pacific Applied Geoscience Commission (SOPAC) and IFREMER/SPT remote sensing centre. The results were used in agricultural and land-use planning, environmental protection, coastal resources assessment and economic development (pearl/ oyster aquaculture).

Future development

For continued remote sensing development the Cook Islands will probably depend more on NZ than a regional facility. There is however, strong support for a regional technical cooperation and development network.

Fiji

Local capability and support

The Government of Fiji is committed to applied geographic information technology development. A Land Information Council and an ad-hoc remote sensing committee, to coordinate national remote sensing activities, have been established.

The Fiji Native Lands Trust Board Land Information System (LIS) is established and operational. Fiji Department of Lands and Survey (DOLS) has a well appointed air survey and photogrammetry section. It has an aerial camera and air-photo processing laboratory and reproduces panchromatic photography on demand. There is no corresponding digital remote sensing capacity. The Fiji Weather Forecasting Centre at Nadi can acquire and process geo-stationary satellite data (4 km resolution) but the equipment is not readily accessible to other agencies.

Current use

Fijian agencies use air-photos for topographic map revision programs (Lands Dept); land resource surveys and land use mapping, irrigation and drainage and fisheries (Primary Industry); regional and environmental planning (Town and Country Planning); bathymetry (Hydrographer, Fisheries, Environment, Public Works); risk–post-disaster assessment (Rural Development, Works). Satellite data has been investigated for mangrove and sediment mapping (SOPAC), watershed land-use analysis (SOPAC/ RRSP/Fiji ad-hoc committee on Remote Sensing), deforestation assessment and training. It is not in operational use except for meteorological purposes.

Fiji has consulted with and/or received assistance from NZ (DOSLI, DSIR); AIDAB; France and UN agencies. SOPAC and the ESCAP Regional Remote Sensing Program (RRSP) were both instrumental in fostering recent interest in remote sensing. The Australian Key Centre for Land Information Studies (AKCLIS) has provided training to Fiji participants through UN and AIDAB-funded courses.

There has been little applied research in Fiji. The University of the South Pacific (USP) is based in Suva but, apart from hosting the Pacific program of the ESCAP RRSP, has restricted academic work to minor course components. USP has an agreement with AKCLIS at the University of Queensland to conduct 'joint research and development of remote sensing applications'. The remote sensing centre of the James Cook University (JCU) of North Queensland is collaborating with a researcher in environmental physics.

Future development

It is expected that Fiji will expand and acquire more image-processing and GIS capabilities both within Government agencies, regional technical agencies and/or the University. Support in the nature of advice, project development assistance and training will be required. Fiji will be a catalyst in the development of remote sensing and GIS for the Pacific.

Fiji is proposing two major land/geographic information systems. The Native Lands Trust Board LIS will be complemented by a computerised cadastre system proposed by F.DOLS and to be developed with NZ aid. The systems will be designed to interchange data.

French Polynesia

Local capacity and support

The Station Polynesienne de Teledetection (SPT) was established as a joint facility by IFREMER and the Territory of French Polynesia (Ministry of Oceans, Energy, Equipment and Posts and Telecommunications). The station is well equipped with the necessary image processing and mapping hardware and software. It maintains a comprehensive archive of SPOT satellite data coverage of French Polynesia and some other Pacific Islands.

Facility objectives are to assist the development of land and reef mapping applications; optimising thematic mapping; promoting applied remote sensing products to the community; and providing information and training. The results of applications projects appear readily transferable to other South Pacific countries.

Current use

The prevailing environmental conditions in French Polynesia are representative of the South Pacific (Loubersac and Wibeaux 1990). SPT project experience illustrates the range of difficulties associated with conventional means of data acquisition (in situ measurements, aerial survey, map campaign costs). SPT geographic studies have also shown that such data are often incomplete and dated. The lack of data disadvantages the people of islands—lagoons from which economic wealth is extracted. SPT has proven the effective application of high and low resolution satellite remote sensing in this part of the world.

Completed and ongoing projects include:

- hydrographic charts (Pacific Standard) adapted to Pacific needs (town planning, tourism, rural development, sea and aquafarming);
- data for geographic information systems to support administration and provide technical data for pearl oyster farms;
- pilot and demonstration projects in FP and Cook Islands, Fiji, SOPAC;
- transfer or make technology accessible to users;
- development of digital elevation models for planning and charts; and
- meteorological-oceanic parameter mapping to assist open-sea fishing and collaborate with global evaluation programs.

Future developments

French Polynesia would not need to be serviced by a regional remote sensing facility. It is more likely that SPT, in cooperation with French facilities in Noumea and elsewhere, will assist regional research, training and applications activities through a technical cooperation and development assistance program.

Guam

Capacity and current use

Applied remote sensing in Guam is restricted to the limited use of aerial photography (ESCAP 1990a). Photography is acquired from private or off-island sources. Island coverage is quite variable in scale. The last complete coverage of Guam was 1975 at 1:24 000. This is quite dated.

The expansion of remote sensing data collection and interpretation was recognised as critical to future planning needs. The principal needs to facilitate such development were training, the establishment of a central storage facility, and associated interpretation equipment.

Future development

The University of Guam may meet some of these needs. A report to the SOPAC Technical Meeting (SOPAC, 1989) indicated that development of an air-photo and remote sensing interpretation course(s) was being considered. The logical strategy would be to develop the University as a small image processing/GIS node for Micronesia, preferably with US donor financing. Guam has already expressed a continuing interest in being part of a Pacific regional technical cooperation and development network.

Kiribati

Capacity and current use

Remote sensing is not routinely used in Kiribati. Survey work is generally restricted to small land masses. A study into the utility of remote sensing for shallow water mapping of the extensive lagoonal areas in the Republic was conducted by the NOAA Fisheries Information Assessment Centre, Washington, USA. This study, together with the work carried out by Jupp et al. (1985) and Loubersac and Wibeaux (1990), demonstrated that good reconnaissance maps of all the shallow waters of Kiribati could be mapped at moderate cost to provide information which currently does not exist.

Future developments

The scope for in-country facilities in Kiribati is not great. The scope for such services to be provided by a regional facility with donor financing is considerable. The focus of such assistance would be the survey of marine resources and the development of bathymetric and resource maps for lagoonal waters.

New Caledonia

Local capacity and support

Applied remote sensing in New Caledonia is carried out by the Laboratoire de Traitement d'images Caledonien (LATICAL) which was established by the Institut Francaise de Recherche Scientifique pour Developpement en Cooperation (ORSTOM) in 1985. There is close cooperation with SPT in Papeete. LATICAL and the DSIR Land Resources remote sensing group in Palmerston North, New Zealand, have discussed joint projects.

Current use

LATICAL has carried out a number of research and applications projects in New Caledonia, Vanuatu and the surrounding seas. Researchers have applied digital satellite remote sensing to marine resource mapping and analysis, detection of seamounts, biological and physical oceanography, mapping of littoral resources (mangroves, seagrasses, wetlands) and the selection of suitable sites for aquaculture projects, erosion mapping as well as developing poster products for the general public.

Future developments

The work related to mapping seamounts and shallow water habitat could be extrapolated to other parts of the Pacific. There is a distinct need to prove that such extrapolation is valid in other areas. There is considerable scope for regional cooperation in this type of applications research integrated with practical project requirements.

The South Pacific Commission (SPC) and the South Pacific Regional Environment Program (SPREP) head offices are both located in Noumea. Both have initiated cooperation with LATICAL but their specific interests are discussed below.

Nuie

Nuie has little need of digital remote sensing. Air photographs are used in relation to cadastral mapping. Any oceanographic work could be readily supported by New Zealand.

Palau

Air-photo interpretation and remote sensing in Palau are at an early stage of applications development. The techniques are potentially useful to development planning particularly in marine areas. Lands and Survey, Agriculture and Forestry and Public Works and Fisheries agencies make use of the existing and available 1975 aerial photography cover. This is now 15 years out of date.

Papua New Guinea

Local capacity and support

Papua New Guinea (PNG) has a well developed land survey and mapping agency. This incorporates an air-photo acquisition and archiving capacity. Photography can be acquired from the department locally. Digital remote sensing capacity is now available but not yet fully integrated in operational programs.

PNG has actively investigated computer-assisted remote sensing and mapping applications and is establishing a national facility. The increased interest is a result of pilot project investigations into the use of remote sensing for marine resources mapping, applications in the private geological survey sector and the forestry experience. A national Papua New Guinea Resource Information System (PNGRIS) was developed with CSIRO assistance and AIDAB and now IBRD (World Bank) financing. PNGRIS was well received but highlighted the need for regular and comparatively inexpensive monitoring of resources.

Australia has had a long association with land survey, land-use and resource analysis work in PNG. CSIRO conducted many land resource surveys in the country both prior to and since independence. CSIRO compiled this data into the PNGRIS. PNG is a member of the RRSP network and supports regional cooperation initiatives.

Current use

Papua New Guinea (PNG) agencies concerned with forestry, land use, agriculture and marine resources, fisheries, the environment and cartographic mapping regularly use aerial photography. Only the Department of Forests has applied interpretation of digital remote sensing data products in an operational sense.

Interest in remote sensing was initiated by the establishment of, and subsequently fostered through growth of remote sensing as an academic component at the Papua New Guinea University of Technology (UNITECH) in Lae. UNITECH Department of Surveying and Land Studies students are exposed to a minimum 60 hours training in various aspects of remote sensing and GIS.

UNITECH has conducted short courses in applied remote sensing in conjunction with James Cook University, Townsville, and the Asian Institute of Technology, Bangkok. Participants included staff from both the public and private sectors.

UNITECH maintains a growing archive of satellite data and is well equipped with remote sensing and GIS software and hardware. In addition to training and academic studies it carries out research and consultancy work. Topics include land information system development and data updating, shallow water bathymetry, a pilot inventory study of Manus Island Province, and selected forestry assessment work.

Future development

PNG sees itself as a leader in the technology in the Pacific. Certainly any regional technical cooperation and development (TCD) in remote sensing must include it. PNG is unlikely to use facilities provided by a regional facility as the capability will develop in-country. Representatives have indicated interest in being part of a regional TCD program especially as it relates to sharing of information on research and applications and training (ESCAP 1990a, 1991).

Solomon Islands

Local capacity and support

The Solomon Islands main air-photo and remote sensing component is contained in the Survey and Mapping Division of the Ministry of Agriculture and Lands. The division has internal branches to support photogrammetry, topographic, forestry and geological mapping, hydrography and lithography. New photographic cover is acquired through contract work generally supported by foreign aid. There is no digital remote sensing capacity.

AIDAB is supporting the development of a national LIS/GIS. A pilot study has been completed and a national system is under development.

Current use

Air photography is used in government agencies responsible for topographic mapping, agriculture, fisheries, forestry and natural resources, geological survey and environment. Some satellite remote sensing pilot studies have been completed for coastal assessment by the Government Geologist with SOPAC assistance.

DSIR (NZ) demonstrated the usefulness of a combination of air-photo and satellite data analysis to map flood and avalanche risk areas for the Guadalcanal coastal plain and for post-cyclone disaster assessment. The studies were well received and there is growing interest in this type of work but no increase in capacity. There is a need for more applied research, training and provision of basic and advanced analysis equipment.

Future developments

Solomon Islands is interested in regional TCD initiatives with emphasis on aerial photography applications as these can be handled locally without complications. They also favour regional development of a remote sensing capacity to service offshore and other isolated area monitoring needs.

Tonga

Local capacity and use

Tonga has only limited local capacity to interpret aerial photography. Current local use is restricted to the Department of Lands, Survey and Natural Resources, the Department of Agriculture and the Department of Forestry.

Full air-photo coverage of Tonga is available through the Lands department. Recently (1989–90), AIDAB funded new total air-photo coverage of the Kingdom. Some satellite data has been acquired and pilot studies completed. Tonga has received assistance with the latter from IFREMER/SPT, the Royal Melbourne Institute of Technology Centre for Remote Sensing (RMIT–CRS) in conjunction with practical lagoon studies carried out by an engineering firm (Riedel & Byrne); and AKCLIS for training purposes.

Future developments

It is expected that Tonga will support strongly any regional TCD initiatives and would make use of regional facilities. It is likely that a small facility will eventually be established in the country, but this would require maintenance and back-up support from outside agencies.

Tuvalu

Tuvalu has minimal internal capacity or capability for any air-photo or satellite data use in resource

survey and analysis. The country does have extensive shallow water lagoon areas which could be inventoried for moderate cost using modern mapping techniques. This could only be achieved on a full support basis funded and implemented externally.

Vanuatu

Local capacity and support

The Department of Lands Survey is the national mapping agency for Vanuatu. Mapping capabilities and capacity have been progressively upgraded with Australian support. Full air-photo cover of Vanuatu is held by the department for local use but additional copies must be acquired offshore. There is no local capacity to acquire new air photography which must be acquired periodically with donor support.

AIDAB supports a forestry resource mapping project which is currently in progress. A computer-assisted information system is under development as part of this project which, while under forestry department control, will provide up-to-date land-use data for other purposes.

Current use

Air photos are being used in the topographic mapping program, the forestry project and for various small land use projects. Their use is generally restricted to large projects and they are not routinely used for general management purposes. Satellite data have been used by ORSTOM researchers to map mangroves and coastal resources for fisheries purposes. They have shown considerable potential and national agencies are interested in the reconnaissance mapping and monitoring capabilities.

Future development

Vanuatu recognises a need for training of staff to interpret hard-copy air-photo and satellite data products. They see some value in a regional mapping support facility that could provide reconnaissance-level maps for development planning and economic studies and for crop monitoring. Vanuatu is a long standing member of the RRSP network and supports a regional Pacific TCD initiative.

Western Samoa

Local capacity and support

Western Samoa has reasonable air-photo processing and visual interpretation facilities principally located in the Lands and Survey Department (DOLS). The Forestry Division of the Department of Agriculture also maintains a drafting office with some interpretation equipment. A number of users have air-photo collections. Air-photo archive coverage dates back to 1954. The most recent cover is 1987 black and white coverage of 70% of the country (ESCAP 1990a). New air-photo coverage must be obtained by contract as there is no air survey camera locally available.

Western Samoa has no facilities for digital image processing. There is good multi-date SPOT satellite cover of both main islands.

A GIS was developed with ADB funding in 1989. The project was implemented by DSIR/ANZDEC. The system covers all terrestrial resources.

Current use

Western Samoa uses aerial photography to develops and produce topographic map series (WS.DOLS); thematic resources planning maps (Department of Agriculture–Land Resource Planning Project; Department of Forests); census map revision (Department of Statistics). Coastal mapping is done by the Observatory Section of DOA with assistance from SOPAC.

Future developments

Western Samoa has indicated (ESCAP 1990a, 1991) the following as the requirements to improve natural resources assessment, mapping and monitoring using remotely sensed data:

- training—air-photo interpretation, orthography, photogrammetry, day to day use of GIS;
- education—inclusion of topics in school curricula; air-photo, satellite image interpretation and GIS applications to be taught at USP's Alafua Campus; and

- regional cooperation and coordination of aerial survey missions to reduce costs; improve equipment; provide advice and training, and provide back-up support.

Regional Specialised Agencies and Programs

Forum Fisheries Association (FFA)

The Forum Fisheries Association is a regional association of independent Pacific Island Countries based in Honiara, Solomon Islands. The FFA's immediate information needs are focused on the accurate determination of the extended economic zone (EEZ) maritime boundary delineation; surveillance of foreign fishing fleets; development of national fisheries management infrastructures; oceanographic systems monitoring and biological research support systems. A large component of the biological research and stock assessment information requirement is provided by the Offshore Fisheries (Tuna and Billfish) and Coastal Fisheries Programs of the SPC.

Remote sensing as defined above can support oceanographic and reef systems assessment and monitoring. Geographic information technology (GIS and mapping hardware and software) can support boundary delineation work. FFA has determined that the major constraints to achievement of success in these areas is the lack of regional expertise and high equipment costs.

Forum Secretariat

The Forum Secretariat supports the regional activities of the South Pacific Forum Countries and is based in Suva, Fiji. At this time the Secretariat does not have any direct interest in either remote sensing or geographic information systems. With an increasing interest in environmental matters this may, however, change. It is expected that any activities in these areas would be in close cooperation with SPREP.

IFREMER

The Institut Francaise de Recherche pour l'Exploitation de la Mer (IFREMER) is the French Oceanographic Institute and has been very active in the establishment of remote sensing in French Polynesia in particular and the South Pacific in general. The joint establishment, with the Government of the Territory of French Polynesia, and activities of the Station Polynesienne de Teledetection (SPT) remote sensing facility in Papeete, Tahiti, have been described earlier.

SPT is a major contributor to the future development and application of remote sensing in the South Pacific. Its practical, demand-driven, orientation has produced some basic parameters for acceptable lagoon bathymetry and resource mapping attributes for Pacific countries which warrant further assessment.

Future research into remote sensing applications should consider the work being done at SPT and its involvement in region-wide studies.

ORSTOM/LATICAL

ORSTOM/LATICAL is based in Noumea, New Caledonia. It has been described above under the relevant country heading. LATICAL has a role in regionwide applications analysis and research. Its proximity to both SPC and SPREP has meant a degree of cooperative work in such areas as fisheries analysis (sea mounts, oceanic chlorophyll distribution); habitat and aquaculture site analysis (prawn culture and aquaculture; trochus habitat—Tetembia Reef; Favidae coral stock inventory; mangrove habitat and species mapping). LATICAL will focus on research and serve the terrestrial and marine resource inventory needs for New Caledonia. It also supports ORSTOM inventory and information requirements in New Caledonia, Vanuatu and elsewhere in the Pacific. There is a growing concern to carry out more development-oriented project support work and there have been discussions with SPT, Papeete, and DSIR, New Zealand, regarding joint activities.

Resource Management Agencies

There are three important regional organisations which deal directly with planning and management of social and natural resources—the South Pacific Applied Geoscience Commission (SOPAC), the South Pacific Commission (SPC) and the South Pacific Regional Environment Program (SPREP). There would appear to be significant cause for close cooperation between them in the development and support of applied geographic information technology in the region. All three carry out resource inventory, assessment, mapping and monitoring activities; have significant technical and computing capabilities; and pro-

vide and/or support such services or activities in member countries. There is significant overlap in country membership although representative national agencies are different.

SOPAC has most experience in the evaluation of geographic information technology to support its own regional and country programs. SPC and SPREP have only recently commenced such evaluation. While accepting the need to examine cost-effective and more efficient techniques there is considerable healthy scepticism about the appropriateness of the high technology aspects to the Pacific Island Countries. All subscribe to the need to progress carefully. Both SPC and SPREP have discussed the issue carefully (ESCAP 1991) and are proceeding to develop small in-house capacities. SOPAC already has such capacity. Specific aspects of current capacity and use and future developments in each organisation are given below.

South Pacific Commission (SPC)

SPC commissioned a study in 1990 to assess the costs and benefits of geographic information technology, including image processing and GIS, to support annual work programs and projects. The study team was also directed to examine the broader issues for the South Pacific Region and identify areas where SPC might be able to support such activities in member countries.

SPC has a number of program areas which have geographic inventory and analysis components to a greater or lesser degree. Air-photo, image processing and geographic manipulation technology would facilitate additional and better analyses for the demography, health, nutrition, agriculture and fisheries programs.

To date only the inshore fisheries program has made use of image processing on an ad-hoc basis (Preston 1991). Preston reports some distinct time advantages over traditional techniques related to marine survey reconnaissance and area mapping Palmerston atoll (SPOT satellite data with assistance from LATICAL; *Bêche de mer* habitat mapping over Ha'apai, Tonga (SPOT data, IFREMER/SPT assistance). A comparison with existing techniques showed a 1:5 advantage in the use of remote sensing, a substantial time and cost saving (if paying expatriate rates!).

The EC study team (Collotte and Meijere 1991) assisted by the author of this report reported that SPC staff were collectively unaware of the benefits GIS and remote sensing could have for ad-hoc and ongoing work programs. All would benefit from mapping and graphic facilities. The team recommended a network approach to data management generally as well as the installation of a small image processing system to support in-house requirements. On the matter of the provision of regional services to member countries the study concluded that the development of a bureau facility would not be cost-effective. SPT, LATICAL and Australian and New Zealand facilities could meet any foreseeable demand for large area project inventory and production mapping work provided funding could be found. It considered that there was a greater need for technical cooperation and development through sharing such resources and focusing on supporting national requirements for training, information exchange, and hardware and software maintenance support for those countries which did install smaller local systems.

The study recommended SPC consider the establishment of a regional program and network which would coordinate technical cooperation and development assistance, and provide advice, training and maintenance support. It suggested any such activity take into account and cooperate closely with the SPREP/UNEP resource information database development and training initiative.

South Pacific Regional Environment Program (SPREP)

SPREP was established by SPC, the South Pacific Forum, the Economic and Social Commission for Asia and the Pacific, and the United Nations Environment Program. SPREP operates under the authority of intergovernmental meetings of governments and administrations participating in the SPREP Action Plan serving the SPREP Convention.

Although concerned with the inventory and monitoring of environmental conditions the SPREP Secretariat did not directly become involved in the use of remote sensing or geographic information technology. The program is currently under going a period of unprecedented growth incorporating responsibilities for inter alia monitoring oceanic pollution (UNEP), inventory of regional ecosystems and assessment for environmental reserves, assessment and establishment of programs to maintain biological diversity (UNDP/World Bank), and environmental assessment and strategic planning support (ADB/UNDP) to member countries. The Secretariat is therefore faced with significant environmental monitoring and assessment data management tasks.

SPREP and the UNEP Global Environment Monitoring System (GEMS) jointly considered the need to promote sound data management. A UNEP-commissioned consultant (Claasen 1990) proposed the development of a program to establish a Global Resource Information Database (GRID) sub-program which would address this need through installation of a sub-regional GIS for the Secretariat and provide

systems and training to participating countries. SPREP and UNEP have agreed to the project and are currently seeking donor funding.

South Pacific Applied Geoscience Commission (SOPAC)

SOPAC (previously CCOP/SOPAC or the Committee for Coordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas) is a regional body consisting of 11 member Pacific countries. The SOPAC Technical Secretariat is based in Suva, Fiji. It is required to assist member governments in the evaluation and promotion of coastal and marine non-living resources and to evaluate coastal engineering issues.

The nearshore and coastal zones are sensitive areas where many resources are concentrated. SOPAC assists countries in the inventory of coastal resources projects listed on its annual workplan. Aerial photography is its most valuable tool and is used in coastal erosion, beach stability and beach sediment budget estimation. In 1986 SOPAC directed that an evaluation be made of satellite remote sensing data as a tool in the process. Pilot studies (Collotte 1990) were conducted using a microcomputer-based image processing system. SOPAC concluded they would have limited use for satellite imagery as the resolution is too low for most of the work required. It is continuing to evaluate remote sensing and GIS technology.

A recent consultancy (1991) carried out by Australian National Resource Information Centre (NRIC) recommended a GIS component be incorporated in a suite of solutions to meet SOPAC's data management needs.

United Nations Group

The United Nations agencies in the Pacific fund or implement some projects which promote the technology or which could benefit from their use. The projects often result in useful spatial data which is of benefit not only to the direct project beneficiaries but which could be of use to multi- and bilateral agencies for the planning of subsequent, and/or evaluation of, development and other projects. The data is often buried in reports.

United Nations Development Program (UNDP)

UNDP is principally a donor agency. UNDP Resident Representatives in the Pacific are located in Port Moresby, PNG; Apia, Western Samoa, and Suva, Fiji. The Fiji office is responsible for 15 countries including Micronesia.

UNDP funded the ESCAP Regional Remote Sensing Program (RRSP) which operated a South Pacific sub-program for two years and extended the Asia–Pacific remote sensing focal point network to the Pacific. UNDP also funds a number of Food and Agriculture Organization (FAO) projects in the Pacific. In the past two years it has also directed attention to the environment with major funding going to environment initiatives (a 1990 South Pacific environment workshop; support to SPREP for national environmental management initiatives; and the Global Environment Facility (GEF) Biodiversity project).

United Nations Environment Program (UNEP)

UNEP has had a long association with the Pacific, particularly SPC and SPREP. Until recently most activity has focused on the UN Regional Seas program administered through the Ocean and Coastal Area Program Activity Centre (OCA/PAC). UNEP also maintained a strong interest in the Association of South Pacific Environmental Institutions (ASPEI) which, until recently, acted as a technical advisory group to SPREP.

GRID, the Global Resource Information Database, was established within the Global Environment Monitoring System of UNEP in 1985. GRID has three essential objectives—to assemble, process and supply geo-referenced environmental information to its users; to provide geographic information system expertise in support of environmental studies and management, and to help institutions and nations wishing to establish geographic information systems to acquire the knowledge and hardware they need. In discussions SPREP and GEMS/GRID agreed that SPREP and its member countries met the needs criteria set by these objectives and agreed to develop a project framework to establish a sub-regional GRID node and associated technology transfer program. UNEP assigned seed funding and other donors are being sought.

The project will include the application of remote sensing to data acquisition and monitoring. The major focus will however be geographic data management.

Economic and Social Commission for Asia and the Pacific (ESCAP)

The UNDP/ESCAP Regional Remote Sensing Program (RRSP) is an Asia–Pacific Region program intended to increase the self-reliance of its participating countries in the mapping and monitoring of their natural resources. The primary purpose of the RRSP in the Pacific was to establish a sub-regional remote sensing program for the South Pacific. The sub-program did not manage to attain all its objectives, primarily because the period of operation was too short (two years). It did however succeed in:

- developing an embryo Pacific technical cooperation network for activities in remote sensing;
- organising a regional remote sensing workshop in Vanuatu in August 1989;
- completing a sub-regional inventory of facilities;
- conducting two short-term in-country (Fiji and Tonga) training courses;
- establishing one pilot project; and
- providing general remote sensing consultations to member-country programs on an as-needed basis.

The sub-program succeeded in putting remote sensing on the agenda in a number of Pacific countries. It was the direct precursor of a number of subsequent activities.

Food and Agriculture Organization (FAO)

FAO is active in the Pacific in a number of resource areas which use or could potentially use remote sensing. These include projects assessing crop production (regional); agricultural census (Fiji, Western Samoa); marine resources mapping (Samoa, Fiji); forestry plantation projects (South Pacific countries); watershed management (Fiji, Western Samoa) and fisheries resource assessment and management (Samoa).

Bilateral Applications, Technical and Training Programs

Australia

Australia has either assisted or provided expertise in a number of areas. AIDAB or Australian Defence Assistance has contributed to the acquisition of aerial photography for a number of Pacific countries. AIDAB has also funded a number of agriculture and/or forest resource information systems in Papua New Guinea (PNGRIS), Solomon Islands (SIFRIS) and Vanuatu (VFRIS).[14]

The Australian Key Centre for Land Information Studies was engaged to conduct two training courses for the UN—ESCAP RRSP in Fiji and Tonga. Part of the funding for these courses came from AIDAB which also supported Fiji's request for an additional course. AKCLIS/University of Queensland have a memorandum of understanding with the University of the South Pacific to carry out joint activities to promote research and education in remote sensing and GIS.

JCU is providing some training and air-photo acquisition development to SOPAC with AIDAB support. JCU is collaborating on joint research projects (shallow water mapping) with UNITECH. It also hopes to work with researchers at USP.

RMIT is active in applied research in Tonga.

Agencies and institutions with particularly relevant experience in the above field, and which have already developed some contacts with the Pacific Island Countries include :

- CSIRO Divisions of:

  Tropical Crops and Pastures (Brisbane, Qld)—terrain surveys, land resource surveys, forest inventories in Australia, PNG, Vanuatu (in association with Qld Forestry Dept);

  Fisheries (Cleveland, Qld)—fisheries surveys, development of GIS for fisheries management, Baitfish site atlas for Fiji;[15]

  Water Resources (Canberra, ACT)—moisture budget assessment, crop assessments, shallow water mapping applications;

  Oceanography (Hobart, Tas.)—sea surface temperature, oceanic currents, applications of radar.

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[14] RIS: Resource Information System; FRIS: Forest Resource Information System

[15] ACIAR funded

- Australian Institute of Marine Science (AIMS), Townsville, Qld—biological oceanography, shallow water mapping, coastal area assessments, current mapping, suspended sediment mapping, sea surface temperature.
- Great Barrier Reef Marine Park Authority (GBRMPA), Townsville, Qld—operational user of remotely sensed data for coral reef and continental shelf resources mapping and monitoring.
- Australian Surveying and Land Information Group (AUSLIG), Canberra, ACT—shallow water mapping, land information systems, data standards, air-photo acquisition.
- State Agencies:

  NSW Dept of Agriculture—crop assessments, area management;

  Qld Dept of Lands; Dept of Primary Industries—crop assessments, terrain and soil studies, shallow water mapping; coastal resources; forestry assessments.

- Universities:

  The Australian National University (ANU), Canberra, ACT—land resource studies.

  University of Queensland (UQ), Griffith University and Queensland University of Technology (QUT) co-established, with the Queensland Government, the Australian Key Centre in Land Information Studies—education and training, land information studies, terrain and environment analysis, shallow water mapping, vegetation mapping.

  James Cook University, Townsville, Qld—marine and coastal surveys, shallow water mapping, geological analysis.

  Royal Melbourne Institute of Technology, Melbourne, Victoria—education and training, research and development, bureau services in dry-land salinity, seagrass, urban planning, fire burn mapping and environmental monitoring.

New Zealand

Most of the comments referring to Australia are also true of New Zealand. An added factor is the long association of New Zealand resource survey and mapping agencies, principally the Departments of Scientific and Industrial Resources and Survey and Land Information, with the Pacific Island Countries (particularly the Cook Islands, Fiji, Nuie, Solomon Islands, Tonga, Tokelau and Western Samoa). New Zealand agencies archive a vast amount of land resource information, mainly soils data, for these countries. They have a special affinity for island conditions and, because of their smaller size, are well accepted by them.

Apart from the above agencies the Universities of Auckland (Auckland) and Massey (Palmerston North) provide training and education and carry out research in applied geographic information technology.

Appendix 2. Remote Sensing Contact Points

Cook Islands

Formal Focal and Contact Point
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Organisation/Agency
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P.O. Box 2222, Government Buildings
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Federated States of Micronesia

Contact Point
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Guam

Contact Point
Mr Timothy Sherwood

Organisation/Agency
Department of Agriculture
Division of Aquatic and Wildlife Resources
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Kiribati

Contact Point
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Land Surveyor

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Marshall Islands

No contact designated

Nuie

Contact Point
Nil

Organisation/Agency
Lands and Survey Section
P.O. Box 67, Alofi
Nuie
Attention:
Mr George Sioneholo
Survey Technician

Northern Mariana Islands

Contact Point
Mr Jack Angello
Public Information Officer

Organisation/Agency
Commonwealth of the Northern Mariana Islands
Office of the Governor
Saipan, Northern Mariana Islands 96950
Telephone: (+) 234 6407

Palau

Contact Point
The Director
Department of Lands and Surveys

Organisation/Agency
Department of Lands and Surveys
Government of Palau
P.O. Box 100, Koror
Palau, 96940

Papua New Guinea

Contact Point
Mr Poka Vagi
Chief Photogrammetrist

Organisation/Agency
National Mapping Bureau
Department of Lands
P.O. Box 5665, Boroko, PNG

Solomon Islands

Contact Point
Mr Namura Teka'ai
Surveyor-General

Organisation/Agency
Survey and Cartographic Division
Ministry of Agriculture and Lands
P.O. Box G13, Honiara
Solomon Islands
Phone (677) 21511
Fax (677) 20094

Kingdom of Tonga

Contact Point
Mr Sione Tongilava
Secretary for Lands, Survey and Natural Resources

Attention:
Mr Saimone Helu
Government Geologist

Organisation/Agency
Ministry of Lands, Survey and Natural Resources
P.O. Box 5, Nuku'alofa
Kingdom of Tonga
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Facsimile: (+676) 23 611
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Tuvalu

No contact designated

Vanuatu

Contact Point
Mr Edwin Arthur
Director of Lands Survey

Organisation/Agency
Department of Lands Survey
Ministry of Lands, Energy and Rural Water Supply
PMB 024, Port Vila
Telephone: (+678) 2427—2214
Telex: 1040 VANGOV NH

Western Samoa

Contact Point
Mr Leali'ifano Joe Soon
Director of Lands and Environment

Attention:
Mr Petelo Ioane
Chief Photogrammetrist

Organisation/Agency
Department of Lands and Environment
APIA, Western Samoa
Telephone: (+685) 22 481
Facsimile: (+685) 20054

Appendix 3. Institutional Contact Points

A. Regional Training and Educational Institutions

Fiji

1. University of The South Pacific

Institute of Natural Resources (RRSP Education Focal Point —South Pacific)	Dr C.R. (Bob) Lloyd, Director Institute of Natural Resources University of the South Pacific P.O. Box 1168, Suva, Fiji Telephone (+679) 313 900/443 Fax: (+679) 300 373
School of Pure and Applied Sciences	Dr Mahendra Kumar, Lecturer (Physics) Department of Physics Telephone: (+679) 313 900/430
Institute of Marine Resources	Dr G.R. South, Director Telephone: (+679) 313 900/386
School of Social and Economic Development	Dr E. Waddell, Professor Department of Geography Telephone (+679) 313 900/546 Mr D. Greenwood, Reader Department of Land Management & Development Telephone (+679) 313 900/584

2. South Pacific Applied Geoscience Commission

Mr Russell Howorth
Training Coordinator
SOPAC, PMB, Meade Road
Suva, Fiji
Telephone: (+679) 381 377

Australia

University of Queensland (Australian Key Centre for Land Information Studies)	Dr Gregory Hill, Director AKCLIS Dept of Geographical Sciences University of Queensland St Lucia, 4067, Qld Australia Telephone (61–7) 377 3224 Fax 371 1115
Centre for Pacific Development and Training (AIDAB)	Mr Grahame Hunter Middle Head Road, Mosman, NSW 2091 Aust. Telephone (61–2) 960 9500
Royal Melbourne Institute of Technology (RMIT) Remote Sensing Centre	Mr Nick Rollings RMIT Dept of Land Information GPO Box 2476V, Melbourne, Vic. 3001 Telephone (61–3) 660 2213 Fax (61–3) 663 2517

James Cook University (JCU) Centre for Remote Sensing	Ms Pauline Catt, Director CRS, James Cook University Townsville, Qld. 4811 Tel (61–77) 815 203 Fax (61–77) 251 348
French Polynesia IFREMER Station Polynesienne de Teledetection	L. Loubersac, Director IFREMER/SPT, BP 601, Papeete–Tahiti, F.P. Telephone (689) 41 06 29 Fax 42 06 98
Universite Francaise du Pacifique	Vice-Chancellor P.O. Box 4635, Papeete–Tahiti Polynesie Francaise Tel (689) 42 1680 Fax 440 131
Guam University of Guam	Dr Frank Kilmer Associate Professor (Geology) University of Guam Mangilao, Guam, 96943
Hawaii East West Center	Dr R. Carpenter East–West Center 1777 East–West Road Honolulu, Hawaii 96849 Telephone: (808) 944 7269 Tx: 743 0331 TEWCH
New Caledonia LATICAL/ORSTOM	Dr Willie Bour, Director LATICAL/Centre ORSTOM BP A5, Noumea Cedex, NC Tel (687) 26 10 00 Fax 26 43 26
Papua New Guinea PNG University of Technology	Paul Millin Department of Surveying & Land Studies P.O. Box 793, Lae, PNG Tel (675) 434 950 Fax (675) 434 951

B. Technical Institutions

Australia

Australian Surveying and Land Information Group (AUSLIG)	C. McMaster, Director, Remote Sensing P.O. Box 28, Belconnen, ACT 2616 Tel (61–6) 252 4411 Fax 51 6326 Mr Drew Clarke, Marketing Manager P.O. Box 28, Belconnen, ACT 2616 Telephone (61–6) 252 6360 Fax: 251 6735
CSIRO Division of Water Resources	Dr David Jupp, Remote Sensing Group P.O. Box 1666, Canberra, ACT 2606 Tel (61–6) 246 5477
CSIRO Office of Space Science and Applications	Mr Jeff Kingwell, Head Science and Applications P.O. Box 225, Dickson, ACT 2602 Tel (61–6) 279 0824 Fax 279 0812

French Polynesia

IFREMER Station Polynesienne de Teledetection	L. Loubersac, Director IFREMER/SPT, BP 601, Papeete–Tahiti, F.P. Tel (689) 41 06 29 Fax 42 06 98

New Caledonia

LATICAL/ORSTOM	Dr Willie Bour, Director LATICAL/Centre ORSTOM BP A5, Noumea Cedex, NC Tel (687) 26 10 00 Fax 26 43 26

New Zealand

Department of Scientific and Industrial Research

1. Division of Land Resources	Peter Stephens, Remote Sensing Applications P.O. Box 8041, Palmerston North, NZ Tel (64–63) 67 154 Fax 66 664
2. Division of Information Technology	Stella Bellis P.O. Box 31–311, Lower Hutt, Wellington, NZ Tel (64–4) 666 919 Fax 690 067

C. Regional Executing Agencies (Resource Evaluation and Planning Orientation)

Forum Fisheries Association (FFA)	Andrew Wright, Research Coordinator FFA, P.O. Box 629, Honiara, Solomon Islands Tel (677) 21 124 Fax 23 995
South Pacific Forestry Development Programme (FAO)	Co-ordinator Private Mail Bag, Port Vila, Vanuatu Tel (678) 3942 Fax 3619
Regional Fisheries Support Programme (FAO)	Robert Gillett, CTA c/o UNDP, PMB, Suva, Fiji Tel (679) 300 802
FAO/AGRT (Remote Sensing)	Z.D. Kalensky Room F906, via delle Terme di Caracallia 00100, Rome, Italy Tel 579 75583 Fax 514 6172
South Pacific Applied Geoscience Commission (SOPAC)	Jim Eade, Deputy Director PMB, Suva, Fiji Tel (679) 381 377 TX 2330 FJ
South Pacific Commission (SPC)	Dr Garry Preston, Snr Fisheries Scientist BP D5 Noumea Cedex, Noumea, New Caledonia Tel (687) 26 2000 Fax 263 818
South Pacific Regional Environment Programme (SPREP)	Dr Vili Fuavao, Director SPREP/SPC, BP–D5 Noumea Cedex, Noumea, New Caledonia Tel (687) 26 20 00 Fax 26 38 18
Global Resource Information Database (GRID/UNEP)	Dr Gary Johnson, Director UNEP/GRID Bangkok, c/o AIT P.O. Box 2754 Bangkok 1051 Thailand Tel (662) 529 2374 Fax 529 2375

Appendix 4. Donor Agency Contact Points

Asian Development Bank	
• Environment Division	Dr Bindu Lohani, Manager Dr Warren Evans, Environ. Specialist P.O. Box 789, Manila, Philippines Tel (632) 834 4444 Fax 741 7961
• South Pacific Regional Office	Jan Rudengren, Economist ADB/SPRO, P.O. Box 127, Port Vila, Vanuatu. Tel (678) 3300 Fax 3183
Australian International Development Assistance Bureau (AIDAB)	
• AIDAB Canberra	Director PACII G.P.O. Box 887, Canberra, ACT 2601 Tel (61–6) 276 4960 Chris Kenna, Multi-country Program Officer, Canberra, PACII
• AIDAB Fiji	Graeme Nicholls Australian Embassy, PO Box 214 Suva, Fiji. Tel (679) 312 844 Tx 2126 FJ
• AIDAB Pacific Regional Team	Grahame Hunter, Natural Resources Middle Head Road, Mosman, NSW 2091 Australia. Tel (61–2) 960 9500
British Development Division in the Pacific (BDDP—UK)	Nicholas Willoughby PMB Suva, Fiji Tel (679) 301 744 Fax 301 218
France	Scientific Attaché Ambassade de France, PMB Suva, Fiji Tel (679) 300 406 Fax 301 894
New Zealand	Development Assistance Division Ministry of External Relations and Trade Private Bag, Wellington, NZ Tel (644) 728 877 Fax 729 596
UNDP–Suva	N. Ringrose, Resident Representative Attention: Ms K. Regan, Asst R.R. Regional Programmes, UNDP, PMB Suva, Fiji. Tel (679) 312 500 Fax 301 718

UNDP–Apia	Resident Representative UNDP, Apia, Western Samoa Tel (685) 23670 Fax 23 672
UNDP–Port Moresby	Mr J Wahlberg, Resident Representative UNDP, P.O. Box 1041, Port Moresby, PNG. Tel (675) 212 877 Fax 211 224
USAID	Mr John Woods, Director, USAID, P.O. Box 218, Suva, Fiji Tel (679) 311 399 Fax 311 905
World Bank	Colin Rees, Asia Environment Division World Bank, 1818 H Street, Washington DC 20433, USA. Tel (1—202) 477 1234 Fax 477 6391

Appendix 5. Recommendations of the SPC/EC Mission to Investigate the Use of Spatial Information and GIS/RS Techniques in the South Pacific

The study team consisted of Mr Johan de Meijere [ITC, 7500 AA Enschede–The Netherlands] and Dr Pascal Collotte [Consultant, Authevernes 27420–France], with the participation of Mr D. van R. Claasen [ACIAR Consultant, Australia].

These recommendations were extracted from the mission's Draft Report (27.12.1990), p.50–51 .

The team made the following recommendations :

To the South Pacific Conference, CRGA and SPC Management

To endorse the need for a regional program in support of providing countries with good and sufficient spatial information, through the application of modern spatial data handling techniques.

To implement this program through SPC and establish a focal point in a network at SPC head office, Noumea.

To have this proposal elaborated for presentation to funding agencies.

To SPC Management

To join the meeting organised by AIDAB/ESCAP in March 1991 with a proposal to house and implement an integrated spatial data management (ISDM) program.

To invite a member of this mission to assist in the meeting and enable the mission to incorporate the findings of the meeting in a final report of this mission.

To contact ESCAP with a proposal to incorporate the RRSP Pacific sub-program within the ISDM program.

To contact SPREP with a proposal to extend the ISDM services to SPREP, to complement the SPREP/ GRID program and prevent duplications.

To contact ORSTOM—Noumea to establish a memorandum of understanding providing for access to spatial data and processing support for SPC member countries and SPC program staff.

To increase SPC's internal GIS/RS capabilities in the short term.

To strengthen the contacts between the programs at SPC through regular technical staff meetings.

To develop an information and automation plan for the next five years.

To develop an 'electronic atlas' of the South Pacific Region within SPC in conjunction with SPREP.

To SPC Programs

To increase their awareness of and competence in GIS/RS through training and selection criteria for new staff.

To intensify contacts with other programs to prevent duplication of efforts and mistakes.

To the EC

To participate in the AIDAB/ESCAP meeting in Suva, March 1991 and support SPC when it presents the ISDM project.

To donor agencies

To support the proposal for the implementation of the ISDM program.

To collaborate closely through the ISDM network on new projects in the area.

To endorse the need for SPC to increase its GIS/RS capabilities.

The mission recommends that a copy of this draft report be distributed to all institutions of which personnel have been visited and interviewed during this mission.

Appendix 6. Recommendations of the ESCAP/AIDAB Working Group Meetings on Regional Cooperation in Applications for Remote Sensing and GIS Technology

The meeting was sponsored by the UNDP/ESCAP Regional Remote Sensing Programme (RRSP) and the Australian International Development Assistance Bureau (AIDAB). It was hosted by the Department of Lands and Survey of the Government of Fiji, 18–22 March 1991.

The working group meeting accepted, with amendments, a proposal for a Regional RS/GIS Network. The project would:

- aim to improve knowledge and management of natural resources in the region by the application of more cost-effective method for data collection and analysis through remote sensing and geographic information technology and processes; and
- provide necessary tools, data and in-country skills to implement national goals at their request, assist countries to integrate RS/GIS technologies into national development planning and environmental management, and encourage cost-effective use of RS/GIS where appropriate and provide a focus for regional cooperation.

The meeting made the following recommendations.

- That its report be referred to all national and territorial governments in the region, and to regional organisations, including those not represented at this meeting.
- All delegates at the meeting should promote the proposal within their governments.
- The support of Australia be sought in providing the services of the AIDAB Natural Resources Adviser, Pacific Regional Team to coordinate progress for one year.
- All national and territorial governments be requested to nominate a liaison officer to assist the coordinator.
- The coordinator and national liaison officers should actively work to get the proposal on as many regional agendas as possible.
- All countries should endeavour to have the report tabled at regional meetings.
- The coordinator should circulate the draft report, collect comments from all national and territorial governments and produce an addendum to the draft report.
- Seek the endorsement of the proposal from the South Pacific Organisations Coordinating Committee.
- Ensure consistency in the manner in which all delegations report back to their governments—to this end a communiqué should be prepared and signed by all delegates and copies carried back to their governments.

Appendix 7. Persons Interviewed in the Course of the ACIAR Mission

The following people were contacted during the course of the mission:

South Pacific Commission
Mr A Baiteke, Secretary General
Mr P Komiti, Deputy Director of Programs
Dr Garry Preston, Senior Fisheries Scientist, Coastal Fisheries Program
Dr Tony Lewis, Program Head, Offshore Fisheries Program
Mr Jeffrey Stander, Computer System Manager, Offshore Fisheries Program
Dr Peter Williams, Statistician, Offshore Fisheries Program
Mr Sundat Balkaran, Demographer, Demography Program
Ms Rosemary Cassidy, Librarian, SPC Library
Ms Carole Martin-Cocher, Computer Systems Manager, SPC
Mr Brian Doyle, Statistician, Socio-Economic Statistical Program
Mr Seumanutafa M. Hazelman, Tropical Agriculturalist, Agriculture
Mr Siliga Kofe, Economist, Economics and Rural Development
Mr A March, Executive Assistant

South Pacific Regional Environment Program
Dr Vili Fuavao, Director
Mr Peter Thomas, Environmental Program Officer

South Pacific Applied Geosciences Commission
Mr Jim Eade, Deputy Director, Technical Secretariat
Dr Russell Howorth, Training Coordinator
Mr Yan Morel, Data Manager

Fiji
Ministry of Lands and Mineral Resources
Mr Albert Queet, Director, Dept of Lands and Survey
Mr Pita Tuiloma, Asst Director, Mapping and Land Information
Mr Alfred Simpson, Deputy Director, Dept of Mineral Resources
Mr Fau'oro Fonmanu, Chief Surveyor (Air), Dept of Lands & Survey
Ministry of Primary Industries
Dr Tim Adams, A/Director, Fisheries Division
Native Lands Trust Board
Mr Tavita Wara, Land Data Base Administrator
Mr Mojeta Mua, Manager, Information System

Tonga
Ministry of Lands, Survey and Natural Resources
Mr Saimone P Helu, Government Geologist

Cook Islands
Department of Survey
Mr Oliver Peyroux, Chief Surveyor

Vanuatu
Department of Lands Survey
Mr Eddie Arthur, Director

Papua New Guinea
Department of Agriculture and Livestock
Mr Balthasar Wayi, Chief Land Use Officer, Land Use Section
Department of Lands
Mr Poka Vagi, Chief Photogrammetrist
Department of Forests
Ms Cathy S Munagun, Forester (Remote Sensing & Data Processing)

Solomon Islands
Ministry of Agriculture and Lands
Mr Nabura Teka'ai, Surveyor General
Mr Fuata Mosese, Senior Surveyor/Photogrammetrist

Western Samoa
Department of Lands and Environment
Mr Petelo Ioane, Chief Photogrammetrist

Regional Institutions

USP Fiji
Mr Rajesh Chandra, Pro-Vice Chancellor (Academic)
Dr Eric Waddell, Professor of Geography
Ms Esther Williams, Librarian
Dr John Morrison, Professor of Chemistry
Dr Robin South, Director, Inst. of Marine Resources
Dr Bob Lloyd, Director, Inst. of Natural Resources
Dr Hugh Williamson, Ocean Resource Management
UN
Ms Kirsty Regan, Assistant Resident Representative, Regional Programmes, UNDP, Suva
Mr He Changchui, Project Manager, ESCAP Regional Remote Sensing Programme, ESCAP, Bangkok
Dr Gary Johnson, Director UNEP/GRID, Bangkok
ORSTOM
Dr Willie Bour, Head, LATICAL (Remote Sensing Laboratory)
Dr J. Dupont, Pacific Region Representative, Noumea
IFREMER
Mr Lionel Loubersac, Director, SPT (Remote Sensing Centre), Papeete
FFA
Mr Philip Muller, Director, FFA, Honiara

New Zealand
Dept of Survey and Land Information
Mr Bill Robertson, Director-General, Surveyor-General of NZ
Mr Graeme Croker, Assistant Surveyor-General (Data Applications)
Mr Clive Soloman, Director of Cartography
Dept of Scientific and Industrial Research
Dr David Leslie, Science Group Manager, Division of Land Resources
Dr Peter Newsome, Head, GIS Services
Dr Bruce Trangmar, Head, Land Evaluation Service
Dr Garth Eyles, Head, Land Resources Catchment Management
Dr Peter Stephens, Remote Sensing Applications
Ms Stella Bellis, Geologist, Division of Information Technology

Dr David Parman, Image Processing Specialist, DIT
Dr Neil Pullar, Project Manager, Land Information Support Group

Australia

Australian Key Centre in Land Information Studies, Brisbane
Dr Greg Hill, Director, Assoc. Professor Dept of Geographical Sciences
Department of Lands, Brisbane
Dr Gail Kelly, Specialist Adviser in Remote Sensing
Mr Graeme Lacey, Head, Remote Sensing Research
Australian Institute of Marine Science, Townsville
Dr Derek Burrage, Biological Oceanographer
Australian Surveying and Land Information Group, Canberra
Mr Grahame Lindsay, General Manager and Surveyor General
Mr Carl McMaster, Manager, Remote Sensing
Mr David Hobson, Manager, Policy and Coordination
Mr Drew Clarke, Manager, Business Development
Mr Dennis Puniard, Director, Operations, Australian Centre for Remote Sensing
Brian Durbridge, Senior Surveyor, GIS
National Resource Information Centre, Canberra
Mr Bob Moore, Data Base Manager
CSIRO Division of Tropical Crops and Pastures, Brisbane
Mr John McAlpine, Princ. Research Scientist, Land Evaluation
CSIRO Division of Water Resources, Canberra
Dr David Jupp, Princ. Research Scientist, Remote Sensing
CSIRO Division of Fisheries
Dr N. Rawlinson, Project Scientist, ACIAR/CSIRO Baitfish Project

ACIAR Technical Reports

No. 1. ACIAR Grain Storage Research Program: research report 1983-84, 63p., 1985.

No. 2. Pastures in Vanuatu, D. Macfarlane and M. Shelton, 32p., 1986.

No. 3. ACIAR Grain Storage Research Program: research report 1984-85, 85p., 1986.

No. 4. Coconut germplasm in the South Pacific Islands, M.A. Foale, 23p., 1987.

No. 5. South Pacific agriculture: challenges and opportunities for ACIAR and its research partners, G.J. Persley and P. Ferrar, 87p., 1987.

No. 6. ACIAR Grain Storage Reseach Program: research report 1985-86, 96p., 1987.

No. 7. Building on success: agricultural research, technology, and policy for development: report of a symposium held at Canberra, 14 May 1987, J.G. Ryan, 39p., 1987.

No. 8. New technologies for rainfed rice-based farming systems in the Philippines and Sri Lanka: report of a workshop held at Iloilo, Philippines, 20-24 July 1987, 39p., 1988.

No. 9. Gaseous nitrogen loss from urea fertilizers in Asian cropping systems, J.R. Freney, J.R. Simpson, Zhu Zhao-liang and Aziz Bidin, 16p., 1989.

No. 10. Bulk handling of paddy and rice in Malaysia: an economic analysis, G.J. Ryland and K.M. Menz, 32p., 1989.

No. 11. Economic prospects for vanilla in the South Pacific, K.M. Menz and E.M. Fleming, 14p., 1989.

No. 12. Biological control of *Salvinia molesta* in Sri Lanka: an assessment of costs and benefits, J.A. Doeleman, 14p., 1989.

No. 13. Rainfed rice production in the Philippines: a combined agronomic economic study of Antique Province, K.M. Menz, 90p., 1989.

No. 14. Transport and storage of fruit and vegetables in Papua New Guinea, K.J. Scott and G. Atkinson, 22p., 1989.

No. 15. Marketing perspectives on a potential Pacific spice industry, Grant Vinning, 59p., 1990.

No. 16. Mineral nutrition of food legumes in Thailand with particular reference to micronutrients, R.W. Bell et al., 52p., 1990.

No. 17. Rice production in Sri Lanka, K.M. Menz (ed.) 51p., 1990.

No. 18. Post-flask management of tissue-cultured bananas, Jeff Daniells and Mike Smith, 8p., 1991.