OPERATIONAL APPLICATIONS OF REMOTE SENSING IN ASIA AND THE PACIFIC

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ABSTRACT:

The Asia-Pacific region contains over half the world's population, and is one of the world's most physically and culturally diverse regions. Remote sensing has been widely used for environmental and resource monitoring, and sustainable development. The paper examines the operational applications of remote sensing in the region, the remote sensing resources available, and the region's training needs.

1. INTRODUCTION

The Asia-Pacific region contains over half the world's population but fortunately also contains the highest density of satellite remote sensing receiving stations. In the passed 20 years the world has undergone a revolution in the development and application of airborne and spaceborne remote sensing data. In the Asia and Pacific region remote sensing technology has become an increasingly powerful tool for environmental and resource monitoring, and sustainable development. This has led the larger countries of the region to develop, launch and acquire data from their own remote sensing systems, and other regional countries to become major users and developers of new application technology.

This paper will examine some of the environmental and resource problems of the region, the operational remote sensing applications that are being developed and used to solve them, and the human resources required to support this work.

2. THE ASIA-PACIFIC REGION

According to the United Nations the Asian-Pacific region stretches from Mongolia in the north to New Zealand in the south, and from the Cook Islands in the east to the Islamic Republic of Iran in the west. It includes the world's largest and the third largest oceans (the Pacific and Indian Oceans), 23 per cent of its land surface, 57 per cent of its population, and the two most populous countries in the world, China and India. The population of the region increased by 20 per cent in the decade ending 1990, and it is expected to increase a further 28 per cent between 1990 and 2005, to reach about 4 billion (ESCAP, 1993a). It includes developed, developing and severely underdeveloped countries, and the most diverse range of cultures and environments. For example although average per capita GNP in 1991 was US$1,790, it varied from US$26,920 in Japan to US$180 in Bhutan and Nepal. About 78 per cent live in areas where the per capita GNP is less than US$500 (ESCAP, 1993b).

In 1990, the proportion of the population of Asia living in rural areas was 70 per cent, and of the Pacific, 27 per cent. However as there is a distinct migration trend towards the cities, it is expected that by 2010, 42 per cent of the population of the region will live in urban areas (ESCAP, 1993a).

Thus it is very difficult to make generalisations about the problems and needs of the region. However, Murai (1991) considers, among the many problems faced by the region, that population explosion, deforestation, soil erosion, overgrazing, desertification and environmental pollution are major problems that can be addressed using remote sensing tools. The F.A.O., for example, reported that tropical forests are being depleted at a rate of 11.5 million hectares per year. According to Rao (1991) the countries of the region share acute environmental problems due to indiscriminate exploitation of natural resources as a result of a growing demand for food, drinking water, energy and pressure on land resources. Deforestation, over irrigation and overgrazing have caused large areas of land to be degraded by erosion , increased salinity, waterlogging or desertification. In India and Vietnam, for example, 50 per cent of the land has been degraded. Although many countries have begun to implement programmes to reduce erosion, the problem remains serious and widespread (FAO, 1989).

The vast expanse of tropical ocean, the climate and the geological history of the region predispose it to natural hazards. Typical of these are typhoons and cyclones, storm surges and floods, bushfires and drought, tsunami, earthquakes and volcanic eruptions. However again these are differentially distributed throughout the region. For example, of the 30 or so major floods worldwide each year, 80 per cent of the victims live in Bangladesh, China and India (ESCAP, 1993c). Forest fires severely affect Indonesia and Australia, while earthquakes and volcanic activity affect an arc stretching from New Zealand to Japan, the ring of fire.

A major problem common to many countries of the region is that rapid economic development is resulting in environment and resource depletion, an overtaxed physical and social infrastructure and the exponential growth of cities due to urban migration and rapidly expanding populations. Currently economic growth in Asia is of the order of 8 per cent per annum compared with only 2 per cent for the whole world. It is predicted that many cities of this region will have doubled their population in the 20 years to the year 2000, for example Shanghai, 13.4 to 22 million, Jakarta, 7.3 to 16 million, Manila, 5.7 to 12 million, and Bangkok, 4.9 to 11 million, (Graetz et al, 1992). In the same time period India may have joined China as the second country to have a billion plus population.

Rapid urbanisation has created or exacerbated many significant problems in the region, including shortage of fresh water, inadequate waste management and mass public transport, and widespread pollution. Meeting the minimal requirements of the rapidly growing population has often driven decision makers to accelerate the pace of economic development with ecologically unsound decisions (Rao, 1991). Strong growth in per capita use of energy, due to rapid economic development, has also contributed to an increase in greenhouse gas emissions and acid rains (ESCAP, 1994).

With the new laws of the sea soon to come into operation countries such as Australia and Indonesia will control vast areas of ocean, and will need to take on the huge task of environmentally managing and controlling these areas. Many Pacific island countries will control greater proportions of ocean than they will of land.

3. REMOTE SENSING APPLICATIONS

To monitor, manage and overcome these problems countries of the region are increasingly turning to remote sensing tools (and GIS) to provide appropriate answers. This is best illustrated by an analysis of the papers published in the Asian-Pacific Remote Sensing Journal over the past five years. The journal is published by the Economic and Social Commission for Asia and the Pacific (ESCAP, United Nations) through its Regional Remote Sensing Programme. While remote sensing specialists of the region publish there application results in a number of international and national journals, it is suggested that those published in the Asian-Pacific Remote Sensing Journal will provide a representative sample allowing an analysis of the different applications and their relative importance.

The papers from 1991 to 1995 were categorised according to application type and also according to sub-regional areas. These sub-regional areas were considered to be North and East Asia (which included papers from China, Japan, Mongolia, Korea), South East Asia (Indonesia, Malaysia, Thailand, Vietnam, Philippines, Singapore, Myanmar), Australasia and Oceania (Australia New Zealand, Papua New Guinea, Fiji), South Asia (India, Pakistan, Bangladesh, Nepal, Sri Lanka) and West Asia (Iran, Saudi Arabia). Table 1 lists the papers from each region by application areas given as a percentage of total papers from that region.

In considering the table it should be recognised that the greatest sample of papers came from the South Asia and South East Asia sub-regions with the other sub-regions being under represented,, nevertheless some conclusions can be drawn for all sub-regions. In the Australasian and Oceania sub-region it can be seen that the greatest percentage of papers were in ocean and near coastal water studies as would be expected given the large coastal and ocean environments under the control of these countries.

Table 1 Remote Sensing Application Papers by Region.

App	SA	SEA	A&O	NA	WA	Tot.
1	9%	6%	34%	25%	0%	12%
2	21	31	22	6	50	22
3	13	3	0	0	0	8
4	13	11	11	13	0	12
5	13	11	0	0	0	10
6	5	9	0	12	50	7
7	7	20	22	0	0	11
8	6	0	0	6	0	4
9	0	0	0	13	0	1
10	13	9	11	25	0	13

Key to Table:

APPLICATIONS

App
1 Lake, Near Coastal, Ocean
2 Land Cover/Use, Management
3 Ground Water, Watershed
4 Agriculture, Productivity
5 Wasteland, Erosion, Desert
6 Urban, Land Use, Planning
7 Forest, Mangroves
8 Topography, Terrain
9 Climate, Atmosphere
10 Theory, Image Analysis

REGIONS

SA South Asia
SEA South East Asia
A&O Australasia and Oceania
NA North Asia
WA West Asia

Tot Total Region %

A further major difference relates to the percentage of papers in watershed and ground water management which are significantly higher in the South Asia sub-region, and the higher percentage of forest related studies in the South East Asia and Australasian and Oceania sub-regions. These results reflect the particular needs of these sub-regions, that is in the case of South Asia the need to provide water for village communities, and the large tropical forests of the other sub-regions which are currently being exploited. Here the desire of sub-regional governments to balance the needs of the economy with the needs of the environment, have led to a greater use of remote sensing tools.

Examining the percentage of total papers it is clearly seen that land cover, land use and land management comprise the greatest application area of the region. It can be suggested that the high percentage of papers in this application area reflects the intense pressure on land due to the very high population and population densities found in the region.

While it is obviously not possible to describe all of the operational applications of remote sensing in the region, a number of examples of different applications in different parts of the region will be highlighted. In India a major project has been the preparation of forest change detection maps for the entire country using satellite data of the period from 1972 to 1975 and from 1982 to 1985. Since then the forest cover of the whole country has been monitored biennially. Studies have also been carried out over selected areas for mapping forest types, for biomass assessment and for monitoring forest plantations. Satellite remote sensing has also been operational used in India for identifying prospective ground water zones to enable ground water exploitation. More than 200,000 boreholes have been drilled using this data, with a success rate of over 90% compared to 45% using conventional methods (Remote Sensing Newsletter, 10, 3), .

The eruption of Mt. Pinatubo in June of 1991 showed the operational utility of using remote sensing and GIS for damage assessment, rehabilitation and development planning activities. Oblique and vertical photography as well as video images were initially used to delineate and map the various areas affected by ashfall and mudflow. Shortly after the eruption MOS-MESSR imagery was acquired and was used to determine the amount and extent of vegetation loss and land cover change in the affected area. A mudflow and siltation risk map for a worse-case scenario was also generated using a combination of aerial photographs, satellite imagery and ground truth data. A physical, socioeconomic and environmental database has been established for the Mt. Pinatubo area, as well as the establishment of a system for updating information in the region. Both optical and radar image data is currently being used to provide update information as mudflows are, even now, still active (Remote Sensing Newsletter, 10, 3).

In Vietnam satellite remotely sensed images have been used for land form mapping. One project used visual interpretation of Landsat

MSS and Spot data to map the Nam Bo delta at 1:250,000 and 1:1,000,000 scales. Supplementary materials used in the study included existing soil, topographic and vegetation maps. Twenty four landscape types were defined and mapped (Remote Sensing Newsletter, 9, 2)

China, as earlier stated, is subjected to major floods each year. One such event in 1991 seriously damaged 21 million hectares of cropland, destroyed 9 million rural homes and injured or killed more than 50,000 people. During the emergency agencies were kept up-to-date through remotely sensed data. SAR data acquisition was conducted over 1,600,000 km^2 of the six most severely flooded areas, with images at 1;50,000 and 1;100,000 being available six hours later and transmitted to flood control headquarters for use in critical decision making. Using the digital image data displayed on monitors, the flood situation could be clearly seen and in particular the effects of severe flooding on flood storage areas could be evaluated quickly (Remote Sensing Newsletter, 9, 2).

Scientists in Japan have been particularly involved in research and development of global models for forests, land cover and estimates of supportable population by crop production (Murai, Ed., 1991). In the latter study a model was developed by first assessing the total area of existing and potential arable land, using the assumptions that forests should be conserved and grasslands can be converted to arable land. Estimates of these areas where based on remote sensing measures and auxiliary data. Supportable population was estimated by dividing crop production by crop consumption per capita.

Weather forecasting is also a major concern and user of satellite remotely sensed data, in the region. The National Weather forecasting Centre at Nadi in Fiji uses the Japanese GMS imagery for determining the position, movement and intensity of weather systems. Data from this satellite is widely used throughout East Asia, Australasia and the Pacific countries for weather forecasting. Significant collaboration occurs between the countries of the region in this important operational application.

A further major use of remote sensing has been in the monitoring and management of coral reefs. Australia has been very active in this area and the whole of the Great Barrier Reef, the largest coral reef in the world, stretching thousands of kilometres down the north-east coast of Australia, has been mapped, both for reefs and water depth, using satellite remote sensing techniques.

A good reference text for applications is "Applications of Remote Sensing in Asia and Oceania - Environmental Change Monitoring", published by the Asian Association on Remote Sensing.

4. REGIONAL REMOTE SENSING RESOURCES

The Asia-Pacific region is very well placed with regard to resources directed towards remote sensing applications. The reception footprint of receiving stations virtually cover the whole region apart from New Zealand and the island nations of the Pacific. In some areas a large overlap occurs. This is particularly so in the South East Asian sub-region, where stations in Thailand, Singapore, Indonesia, and a soon to be established reception facility in Malaysia have considerable overlap. There are at least 10 reception facilities covering the region, although not all receive data from all available remote sensing satellite systems.

Three countries of the region have launched remote sensing satellites, these being India, China and Japan, which are supported by sophisticated ground support facilities and application programmes.. These range from high spatial resolution optical systems, some with stereoscopic capacity, to NOAA-like and meteorological satellite systems and synthetic aperture radar systems. Australia, Japan, India and China have also been very active in the development of airborne optical and micro wavelength systems. Other countries have developed specialised application industries, in particular Thailand, Malaysia, Indonesia, Australia and New Zealand.

Countries of the region have also developed a range of remote sensing image analysis, photogrammetric and GIS software. For example the Australian developed ER Mapper is one of the world's largest selling image analysis software. Virtuozo, a softcopy photogrammetric system, which is now making inroads on the world's markets, was developed in China and commercialised in Australia. In-house country developed GIS and remote sensing software are widely used in India, China and Japan in preference to systems developed and marketed from countries outside the region.

The region is also very well supported by education and training institutions and programmes. Major institutions for university based training and research, include the Wuhan

Technical University of Surveying and Mapping and Peking University, China, the Asian Institute of Technology, Bangkok ,Thailand, the University of New South Wales, Sydney, Australia, and the Indian Institute of Remote Sensing, Dehradun, India. Many short course and project oriented training programmes are organised and coordinated through the ESCAP Regional Remote Sensing Programme, with offices located in Bangkok, Thailand, and in addition many bilateral education and training programmes are conducted each year throughout the region.

Supportive of all the training, research and application activities is the Asian Association on Remote Sensing, which assists, coordinates, collaborates, publishers and general brings together the scientists and application specialists of this very diverse region. Each year the Association holds a conference in one of the member countries of the region, and for those readers who have attended any of these conferences they will surely remember the warm, family of nation atmosphere that prevails. The Association has been the major catalyst in developing the very strong links that now exist in the region.

5. REGIONAL TRAINING NEEDS

While the region is well served by training and educational institutions these are unable to train all the skilled staff that are required to support operational applications of remote sensing. The numbers required can be estimated from a comparison with developed countries, particularly Europe and North America.

It is considered that there is a close relationship between a countries requirements for surveying and mapping personnel and those required for remote sensing. For example China has approximately 100,000 surveying and mapping personnel (Brandenberger, 1991) and 10,000 remote sensing specialists, India 40,000 and 5,000, and Australia 20,000 and 2,000 (estimate), respectively. Thus an approximate 10 to 1 relationship would seem to exist.

It would also be reasonable to assume that the number of surveying and mapping personnel, and thus remote sensing specialists would be directly related to the area and population of countries, as this is a measure of the countries resource, infrastructure and mapping needs. More precisely the personnel numbers required should be closely related to the countries population density. Figures from Brandenberger (1991) supports this contention for advanced industrial countries or regions, as can be seen from Table 2, which are assumed to have optimum personnel for there needs.

Table 2 Comparison of Surveying and Mapping Personnel, and Population Density

Country or Region	**Personnel, 1000 km^2**	**Population Density,km 2**
Europe	67.7	99.8
N.America	10.8	17.0
France	64.0	100.5
Australia	2.6	2.1
Canada	2.5	2.6
USA	19.2	25.9
New Zealand	11.2	12.6
Sweden	14.4	18.5
Switzerland	90.8	154.6

Thus a good relationship between the optimum number of surveying and mapping personnel can be given by

$$S = 0.65 \times A \times P$$

where A = area in thousand km^2.
P = population density per km^2.
and S = total number of surveying and mapping personnel.

or more simply

$$S = 650 \times TP$$

where TP = total population in millions

Considering the 10 to 1 relationship to give remote sensing specialist numbers and assuming a need to replace or retrain staff every ten years, then

$$R = 6.5 \times TP$$

where R = remote sensing specialists required to be trained per annum.

Table 3 provides an estimate of the remote sensing personnel required to be trained each year (based on their population) with a guesstimate of the numbers currently being trained in some countries of the Asia-Pacific region. These latter figures are based on various country reports and the author's personal experience in the region. The numbers represent both postgraduate degree level and intensive short course training.

Table 3 Comparison of Current Personnel Training and Training Needs Per Annum.

Country	Required Trained p.a.	Current Trained p.a.
Australia	115	120
Bangladesh	694	50
Cambodia	51	3
China	7050	1000
N.Korea	140	70
S.Korea	277	30
India	5130	500
Indonesia	1128	70
Japan	800	1000
Laos	30	5
Malaysia	108	100
Pakistan	684	100
Philippines	372	100
Singapore	18	10
Sri Lanka	110	4
Thailand	347	170
Vietnam	408	50

It can be seen that there are some serious shortfalls in staff being trained in many countries of the region, while Malaysia, Japan and Australia, are well placed, with numbers being trained approximately equalling the numbers required. Many countries are accelerating their training programs in both remote sensing and GIS and should reach the optimum numbers in the early part of next century, however some countries with lower economic growth and who have commenced from a lower base, due to war or other political reasons, may not reach appropriate levels for many years to come. Unfortunately it is these countries that most need remote sensing in operational applications.

6. SUMMARY AND CONCLUSIONS

The diversity of the Asia-Pacific region creates resource and environmental problems unmatched elsewhere in the world. However remote sensing has been widely accepted as a tool to map resources and monitor the environment, and considerable advances have been made in operational applications of remote sensing. The larger countries of the region have launched sophisticated remote sensing satellite systems, and others have developed specialised software to support a wide range of applications. While world class education and training facilities exist in the region, many countries are facing a shortage of staff due to the limited numbers being trained. This latter problem will need to be overcome if all countries of the region are to reap the benefits of remote sensing.

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