REMOTE SENSING TECHNOLOGY AND ITS APPLICATION TO HYDROCARBON EXPLORATION IN INDONESIA *)

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ABSTRACT

Remote sensing is defined as collecting and interpreting information on a target without being in physical contact with the object.

Today remote sensing technology is enable to produce high quality of images including aerial photograph, landsat, SPOT and radar imageries. Development in digital image processing supported by hightech computer hardware and software produce remote sensing data that are not only usable for reconnaissance study, but also for detail analysis.

Remote sensing has proved to be powerful tool in hydrocarbon exploration. In Indonesia, oil companies have widely used remote sensing technique in finding out hydrocarbon. Integration of remote sensing data with other subsurface exploration data has led to the discovery of several major oil fields in the region.

1. INTRODUCTION

Remote sensing is broadly defined as collecting and interpreting information on a target without being in physical contact with the object. Aircraft and satellites are the common platforms for remote sensing observations.

Aerial photography is the original form of remote sensing and remains the most widely used method. Aerial photography analyses have played major roles in the discovery of many oil and mineral deposits around the world. In the 1960's, technologic developments of the electronic spectrum enabled the acquisition of images at other wavelengths, including thermal infrared (IR) and microwave (Figure 1). The development and deployment of manned and unmanned earth satellites began in 1960's and provided an orbital vantage for acquiring images of the earth.

The science of remote sensing has matured appreciably over the past decade. There were many technical advances have occurred. High-quality radar images have been acquired from satellites. The spatial and spectral resolution of images throughout the electromagnetic spectrum have improved. Digital processing of image data is more advanced and more widely used. Future technical advances will provide even finer spatial and spectral resolution with the goal of identifying materials rather than simply distinguishing broad categories of materials. Major technical advances are occurring in the image processing field. Costs of computer hardware and software are dropping, while their capabilities are increasing.

In the field of resource exploration, remote sensing is considered as one of the many tools to help finding oil, gas or ores deposits. Small-scale satellite images of relatively low spatial resolution, such as Landsat MSS, provide regional data from which one can recognize sedimentary basins and potential metal-bearing trends. Satellite and aircraft images of higher spatial resolution, such as Landsat TM, aircraft radar and thermal IR images, enable the interpreter to recognize local and more detail structures. In all these cases, however, remote sensing is an initial step that must be followed by field checking, sampling, and geophysical surveys before wells are drilled or shafts are sunk. Such caution is required because hydrocarbon and mineral resources occur at some depth in the earth, and remote sensing images only record surface phenomena from which subsurface exploration targets must be inferred.

Remote sensing is increasingly developing into a valuable tool for resources inventory and evaluation in planning and development. This is particularly the case for countries with large territory. The use of this technology is even more beneficial for developing countries where sufficient data for planning are usually lacking. Indonesia is a developing country of large territory, most of which being of difficult access due to mountainous areas and forest cover. Therefore, application of remote sensing technology in Indonesia is highly recommended.

Indonesia has already made large scale investments to acquire a coverage of her territory with aerial photographs and airborne radar. Facilities were also developed to receive and process data provided by Landsat and SPOT satellites. Today there is a host of Indonesian organizations which in one way or another call upon remote sensing data sources.

Three groups of organization can be recognized :

- Remote sensing agencies at a national level : LAPAN - the National Institute for Aeronautics and Space; BAKOSURTANAL - the Coordinating Agency for Surveys and Mapping
- Research institutions and universities level : LEMIGAS - the Research and Development Center for Oil and Gas

Technology; GRDC, Bandung; IPB, Bogor; PUSPICS - the Remote Sensing Laboratory of BAKOSURTANAL and Gadjah Mada University, Yogyakarta; etc.

- Government departments and operational agencies level : Ministry of Forestry, Central Bureau of Statistics.

2. REMOTE SENSING TECHNOLOGY

Remote sensing technology provides the users with products of pictures, very special images taken from airborne system or satellites crossing or orbiting above the earth with equipment that scans the earth's surface through visible and invisible wave lengths of the light spectrum.

Image processing is other side of remote sensing technology. Many types of remote sensing images are routinely recorded in digital form and then processed by computers to produce images ready for interpreters to study. Computers are employed for sophisticated interactive manipulation of the data to produce images in which specific information has been extracted and highlighted. Advancement in image processing technology gives better image to interpret.

Below we present briefly the technology of remote sensing in airborne and spaceborne system and image processing as well.

Aerial Photographs

Aerial photographs are photographs of earth's surface that obtained by sensing the earth's surface from aircraft. Aerial photographs were the first form of remote sensing imagery, and they remain the most widely used images today. In the enthusiasm for satellite images and new forms of airborne remote sensing, one should not overlook the advantages of aerial photography.

Geologic mapping and exploration commonly begins with an analysis of photographs. In the early 1970's interpretation of aerial photographs led to the discovery of several major oil fields in Salawati Basin of Irian Jaya.

Aerial photographs are a versatile and useful form of remote sensing for the following reasons :

1. The film provides excellent spatial resolution and has a high information content.
2. Photographs cost relatively little.
3. Different films provide a sensitivity range from the UV spectral region through the visible and into the reflected IR region.
4. Low-sun-angle photographs enhance subtle topographic features that are suitably oriented with respect to the sun's azimuth.
5. Stereo photographs are valuable aids for many types of interpretation.

The principal drawbacks of aerial photographs are as follows :

1. Daylight and good weather are necessary to acquire them.
2. In the shorter wavelength regions, atmospheric scattering reduces their contrast ratio and resolving power.
3. Variations in reflectance are recorded in uncalibrated fashion, which hamper quantitative interpretation.

The advantages often outweigh the disadvantages, and one should evaluate aerial photographs as a possible data source for any remote sensing investigation.

Landsat Images

Landsat images are images of the earth's surface that produced by regularly-earth orbiting satellite called Landsat (land satellite). Landsat is an unmanned system that prior to 1974 was called ERTS (Earth Resources Technology Satellite). Landsat program is largely responsible for the growth and acceptance of remote sensing as a scientific discipline.

The Landsat program is a major advance in remote sensing. The advantages of Landsat images are as follows :

1. Cloud-free images are available for most of the world with no political or security restrictions.
2. The low to intermediate sun angle enhances many subtle geologic features.
3. Long-term repetitive coverage provide images at different seasons and illumination conditions.
4. The images are low in cost.
5. IR color composites are available for many of the scenes. With suitable element, color composites may be made for any image.
6. Synoptic coverage of each scene under uniform illumination aids recognition of major features.
7. There is negligible image distortion.
8. Images are available in a digital format suitable for computer processing.
9. Limited stereo coverage is available.
10. New imaging system called TM (thematic mapper) provides images with improved spatial resolution (30 by 30 m), extended spectral range, and additional spectral bands.

SPOT Images

The SPOT images are images of the earth's surface that produced by SPOT Satellite. The SPOT (Systeme Probatoire d'Observation de la Terre) program was conceived and designed by the French Centre National d'Etudes Spatiales (CNES). The first SPOT satellite, SPOT 1, was launched on February 22, 1986. The spatial resolution of the images are 10 by 10 m to 20 by 20 m.

It is frequently claimed that because of their high spatial resolution, SPOT data quality are comparable to aerial photographs. SPOT images are also suitable for stereo viewing.

Thermal Infrared Images

Thermal infrared (IR) images are images of the earth's surface that produced by satellite or aircraft which record infrared waves of earth's material. Satellite acquisition of thermal IR images began in 1960. In 1980 the thermal infrared multispectral scanner (TIMS) was developed.

Thermal IR images are useful for many applications, like :

- Differentiation of rock types. Denser rocks, such as igneous rock and sandstone, have higher thermal inertias than less dense rocks, such as clay and siltstone.
- Mapping geologic structure. Faults may be marked by cool linear anomalies. Folds may be indicated by the thermal pattern caused by the outcrops of different rock types.
- Mapping geothermal areas, sea ice, subsurface coal fires, detecting oil spill, thermal plumes, and current patterns in water bodies.

Radar Images

Radar images are images of the earth's surface that produced by radar (radio detection and ranging) tool from aircraft or satellite. Radar is an active remote sensing system because it provides its own source of energy. The system illuminates the terrain with electromagnetic energy, detects the energy returning from the terrain, and then records it as an image.

The continuous-strip mapping capability of Side-Looking Airborne Radar (SLAR) was developed in the 1950's to acquire reconnaissance images without the necessity of flying over politically unfriendly regions.

Radar images can be produced by both aircraft and satellite systems. Since 1981 images have been produced by radar of space shuttle, called as SIR (Space-shuttle Imaging Radar).

Because radar is an active system that supplies its own illumination, images can be acquired at night and through cloud cover. On many images of heavily forested terrain, geologic features are still clearly expressed.

Image Processing

Most of remote sensing data are recorded in digital format and processed by computers. The development of faster and more powerful computers, peripheral equipment and software packages that are suitable for image processing have made digital image processing more sophisticated and giving promisingly better image. The strangely beautiful pictures of the earth's surface are produced in image processing workstations.

Image-processing methods may be grouped into three functional categories :

- Image restoration : compensates for data errors, noise, and geometric distortions introduced during the scanning, recording, and playback operations.
- Image enhancement : alters the visual impact that the image has on the interpreter in a fashion that improves the information content.
- Information extraction : utilizes the decision-making capability of the computer to recognize and classify pixels (smallest unit of image) on the basis of their digital signatures.

The digital image processing is obviously benefit if improvements in the accuracy of geologic and other maps can be made. If image processing reveals a previously unrecognized geological pattern that in turn leads to the discovery of major oil fields, the cost benefits are obvious.

Today most of big oil companies have their own image processing center. The ability to process and interpret remote sensing data in-house results in significant cost reduction relative to purchasing these services from vendors, while maintaining confidentiality.

3. APPLICATION TO HYDROCARBON EXPLORATION

Remote sensing technology has proved to give a great benefit in discovering energy and mineral resources. This technology is usable both in reconnaissance and detail exploration. The potential of sedimentary basin which may contain hydrocarbon can be assessed by remote sensing methods.

Most remote sensing imagery is, by itself, just a pretty picture. In order to get added value in petroleum exploration it must be used :

- as a direct hydrocarbon indicator (seep detection),
- to help delineate drilling prospects, or
- to streamline part of another process (like seismic planning, pipeline layout).

For oil exploration, remote sensing is especially valuable in poorly mapped regions. Landsat images are also useful as base maps and for planning field operations. In forested areas of perennial cloud cover, radar images acquired from aircraft and satellites make it possible for geologists to map lithologic terrain and geologic structures. Interpretation of Landsat images can reveal the presence of a previously unrecognized surface structures. Integration with the interpretation results from other exploration methods may subsequently discovered prospects viable to be drilled.

Hydrocarbon exploration begins with regional reconnaissance and is succeeded by progressively more detailed (and expensive) exploration method that culminate in drilling a wildcat well. Below are the role of remote sensing in hydrocarbon exploration steps.

1. Regional remote sensing reconnaissance. Small-scale Landsat mosaics covering hundreds of thousands of square kilometers are especially useful in this phase. The objective is to locate sedimentary basins, which are areas underlain by thick sequences of sedimentary rocks.

2. Reconnaissance geophysical surveys. Aerial magnetic surveys are made to produce maps that record the intensity of the earth's magnetic field. Sedimentary basins have lower magnetic intensities than do areas underlain by nonsedimentary rocks such as granite and volcanic rocks. The aerial magnetic maps thus confirm the presence of sedimentary basins. Surface gravity surveys are made that record the intensity of the earth's gravity field. Sedimentary rocks have a lower specific gravity than nonsedimentary rocks; hence sedimentary basins are shown by lower values on the gravity maps. Gravity and magnetic maps may also show regional structural features.

3. Detailed remote sensing interpretation. Individual digitally processed Landsat images are studied to identify and map geologic structures, such as anticlines and faults, that may form oil traps. Promising structures may be mapped in detail using stereo pairs of aerial photographs. Radar images are used in regions of poor weather where it is difficult to acquire good photographs and Landsat images. At this stage, geologists go into the field to check the interpretation and collect samples of the exposed rocks.

4. Seismic surveys. Explosives or mechanical devices are used to transmit waves of sonic energy into the subsurface, where they are reflected by geologic structures. The reflected waves are recorded at the surface and processed to produce seismic maps and cross sections that show details of subsurface geologic structure.

5. Drilling. Wildcat wells are drilled to test the subsurface targets defined by preceding steps.

From the foregoing exploration steps it is clear that remote sensing is one of the many exploration tools now available to the industry.

The cost of activities to get subsurface data before drilling wildcat well is so high that oil companies must find out the most promising area efficiently in the earlier stage of exploration. For this purpose, remote sensing is employed as a powerful prospecting tool. In this way remote sensing plays an important role in the economical and time-saving oil and gas exploration.

Aerial photograph, Landsat and radar images can relatively inexpensive and quickly interpret geologic structures like folds or faults that may form petroleum traps at some depth in the earth. The interpretation of geologic structures is essential to the process of defining subsurface hydrocarbon traps.

As real examples of application to hydrocarbon exploration, we can reference to the case from Sudan , Africa *(Sabins, 1987)* where remote sensing has played important role in discovering oil fields, and from Tarim Basin, NW China *(Nishidai and Berry, 1990)* where remote sensing was used as basic tool to assess hydrocarbon prospect of the basin.

In Sudan, Chevron used remote sensing data to define sedimentary basin in the concession area and to locate prospective areas. Remote sensing survey was begun in 1975, followed by geophysical survey and detail analysis of remote sensing data. Drilling was started in 1977 with first five wells were dry. The first discovery of oil was in 1979. Up to 1982 Chevron had developed four major oil fields in the area (Figure 2). Full extent of the fields was not known at early stage of development, but reserves exceed several hundred million barrels.

For Tarim Basin, *Nishidai and Berry (1990)* showed that detail analysis of Landsat imagery, integrated with published geological and geophysical data has provided the basis for a re-examination of the structural geology of the area and has enabled a new interpretation of the tectonic development of the basin. It is shown that a remarkable basin-wide structural framework may be delineated on the basis of the imagery.

4. APPLICATION IN INDONESIA

Indonesia, like many other countries, tries to improve the monitoring and management of its development activities and of its numerous natural resources. However, the large spatial extent of the country combined with the fact that many areas cannot be easily accessed, makes traditional resource inventories difficult, costly, and time consuming. Moreover, today, most information must be available in apparent-real time. In this context, remote sensing technology which provides an opportunity to fulfill these requirements is becoming an essential tool for development activities.

Remote sensing data in forms of aerial photograph, Landsat, SPOT, and radar images have been used in Indonesia since 1970's. As recently as the early 1970's interpretation of aerial photographs led to the discovery of several major oil fields in Irian Jaya.

The heavy forested and excessive cloud covered areas of Indonesia have made SLAR useful for oil exploration. This image has essentially all-weather capability and the ability to enhance geologic structure in forested terrain. CONOCO in 1975 run a structural reconnaissance mapping in Irian Jaya, Indonesia, using SLAR images. Total Indonesie in 1975 published a SLAR mosaic of the Mahakam delta on the east coast of Kalimantan. The anticlinal trends of the onshore oil fields are clearly visible on the mosaic despite the dense vegetation cover.

The NASA Space Shuttle mission in November 1981 acquired images of portions of the earth with a synthetic aperture radar system at spatial resolution of 38 m. This mission was called as SIR-A (Space Shuttle Imaging Radar-A). The SIR-A mission of Indonesia including parts of Irian Jaya, Kalimantan, Java, and some of the smaller islands (Figure 3).

Persistent cloud cover in this tropical region has hampered acquisition of aerial photographs and Landsat images, but the SIR-A images are of excellent quality *(Sabins, 1983)*.

Another remote sensing application in Indonesia was conducted by Elf Aquitaine in 1989 on the Ritan and Maruwai areas, upper Kutei Basin, East Kalimantan. SAR (synthetic aperture radar) images were used to evaluate the tectonic framework and paleogeographic evolution of the upper Kutei Basin. SAR data was manually reinterpreted at 1: 250,000 scale. They interpreted linear patterns that correlated with joint data of the area.

In 1987 Research and Development Exploration and Production (EP) PERTAMINA cooperated with Centre for Geotechnological Research and Development of the Indonesian Institute of Science (LIPI) carried out hydrocarbon exploration in Timor Island by applying remote sensing methods *(PERTAMINA-LIPI, 1987)*. In this investigation aerial photographs and Landsat imageries were used (Figure 4).

The main objectives of the investigations are : firstly, to assess the possibility of using Landsat imagery as a tool in hydrocarbon exploration; secondly, to assess the hydrocarbon potential of the Timor Island.

All structural elements like folds, lineaments representing faults or fractures, circular features, etc., have been interpreted from the Landsat imagery. Whenever possible, aerial photographs assisted in more detailed structural analysis. Structures detected on aerial photographs frequently represent only segments of much larger structural features which can be detected on Landsat images.

In 1989 PERTAMINA and LIPI carried out a similar study for Eastern Java. In this study, Landsat and SPOT images were used (Figure 5). The images were on a 1 : 250,000 scale. The CCT's (Computer Compatible Tape) were then digitally processed with feature enhancement. False coloured composite hard copies were then made from the processed CCT's. The SPOT data consisted of prints-outs, both false colour composites and panchromatic black and white.

By using satellite imagery certain results might be expected. The most prominent amongst those are : updated geologically lineaments and circular features. The most striking phenomena on satellite imagery were lineaments or linears.

In addition to linear pattern, *PERTAMINA and LIPI (1989)* also recognized several circular features on the images. Circular features are generally interpreted as indications of the existence of near-surface geologic phenomena, with a more or less circular outline. The clay-diapirism is represented at the surface as circular outline. It should be studied for its potential relevance to hydrocarbon entrapment and agent of structural deformation.

From the study, it is found that the available Landsat imagery and CCT's proved of great help to distinguish the fundamental geological structures and some of the principal geologic units in Eastern Java. This kind of study may be included in standard early phase exploration activity, especially for remote areas with difficult access.

The examples of remote sensing application in hydrocarbon exploration that presented above are only a small part of whole remote sensing surveys for hydrocarbon exploration done in Indonesia. The PSC (Production Sharing Contractor) or JOB (Joint Operation Body) in Indonesia generally carry out remote sensing survey for their areas, mainly as reconnaissance study. Several of them used the images for detail study after enhancing images by CCT processing. For examples, Huffco did remote sensing survey for East Kalimantan in 1980's; Amoseas Indonesia conducted remote sensing interpretation for the Asem-Asem Basin in 1985; PERTAMINA-Trend JOB did a remote sensing data acquisition and interpretation for Tuban Block, East Java in 1989; PERTAMINA-Stanvac JOB studied Landsat and SPOT images for Gundih Block, Central Java in 1989; Mobil Oil carried out remote sensing survey for Lengguru Block, Irian Jaya in 1991; and Ultramar-Lasmo did SLAR survey for Runtu Block, East Kalimantan in 1991. Location of the areas surveyed is shown in Figure 6.

5. CONCLUSIONS

1. Remote sensing technology has produced various kinds of images (aerial photograph, satellite and radar images) that are very helpful for multipurposes earth's surface study and evaluation.

2. Updating technology of digital image processing has made remote sensing data are valuable not only for reconnaissance study, but also for detail analysis. It can be used during reconnaissance activity of exploration to detail planning of operation.

3. In Indonesia remote sensing technique have been widely used by oil companies as one of the valuable tool in exploration. Remote sensing data which integrated with other exploration data have made resource exploration more successful.

4. Indonesia is a developing country of large territory, most of which being of difficult access due to mountainous areas and forest cover. Therefore, application of remote sensing technology in Indonesia is highly recommended.

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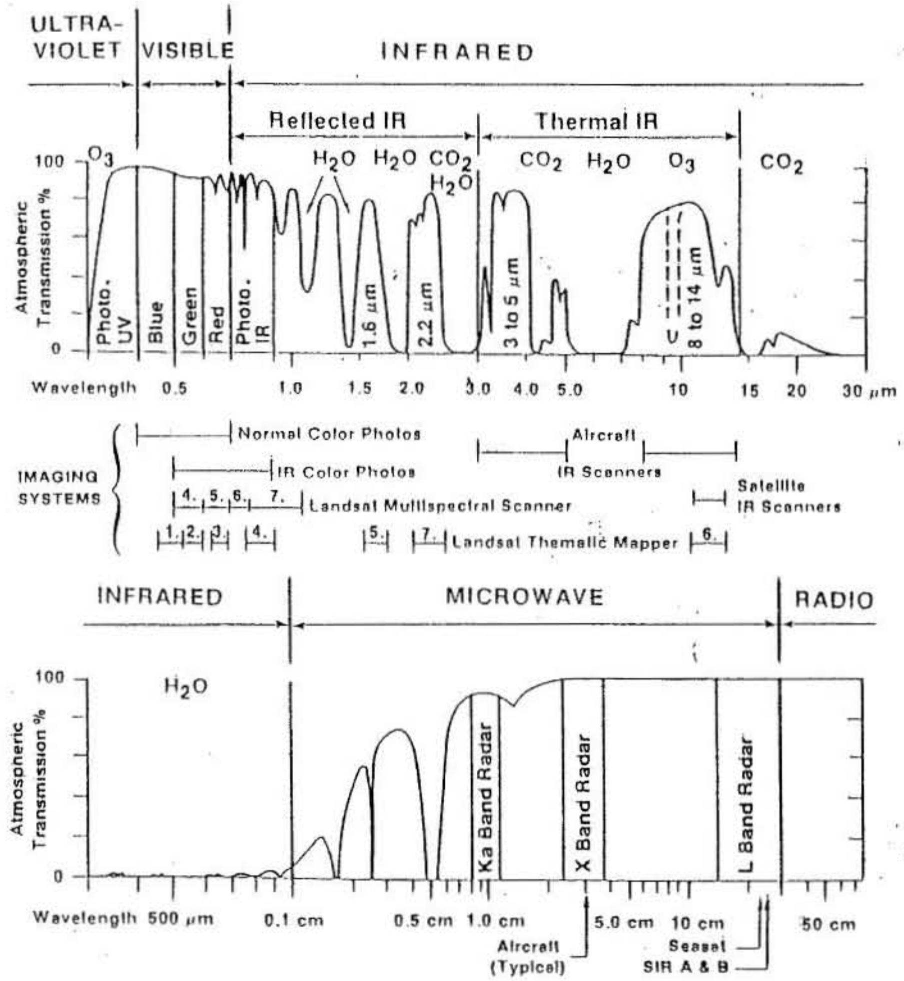
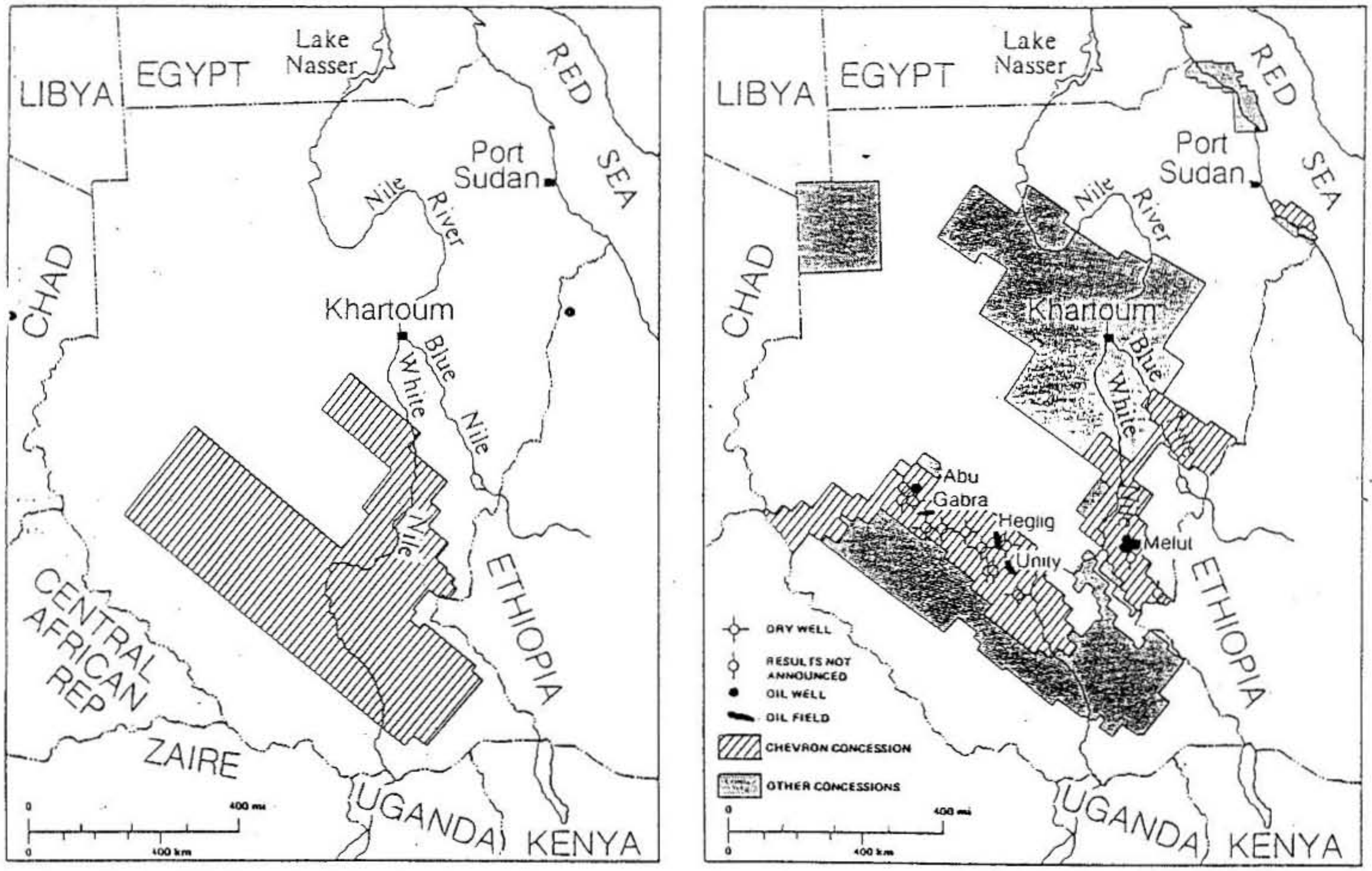


Figure 1 Spectrum region of electromagnetic wave and commonly used remote sensing system (from Sabins, 1987).



A. ORIGINAL CHEVRON EXPLORATION CONCESSION GRANTED IN 1974.

B. STATUS OF EXPLORATION AND CONCESSIONS IN 1982.

Figure 2 Maps showing status of oil exploration in the Sudan (from Sabins, 1987).

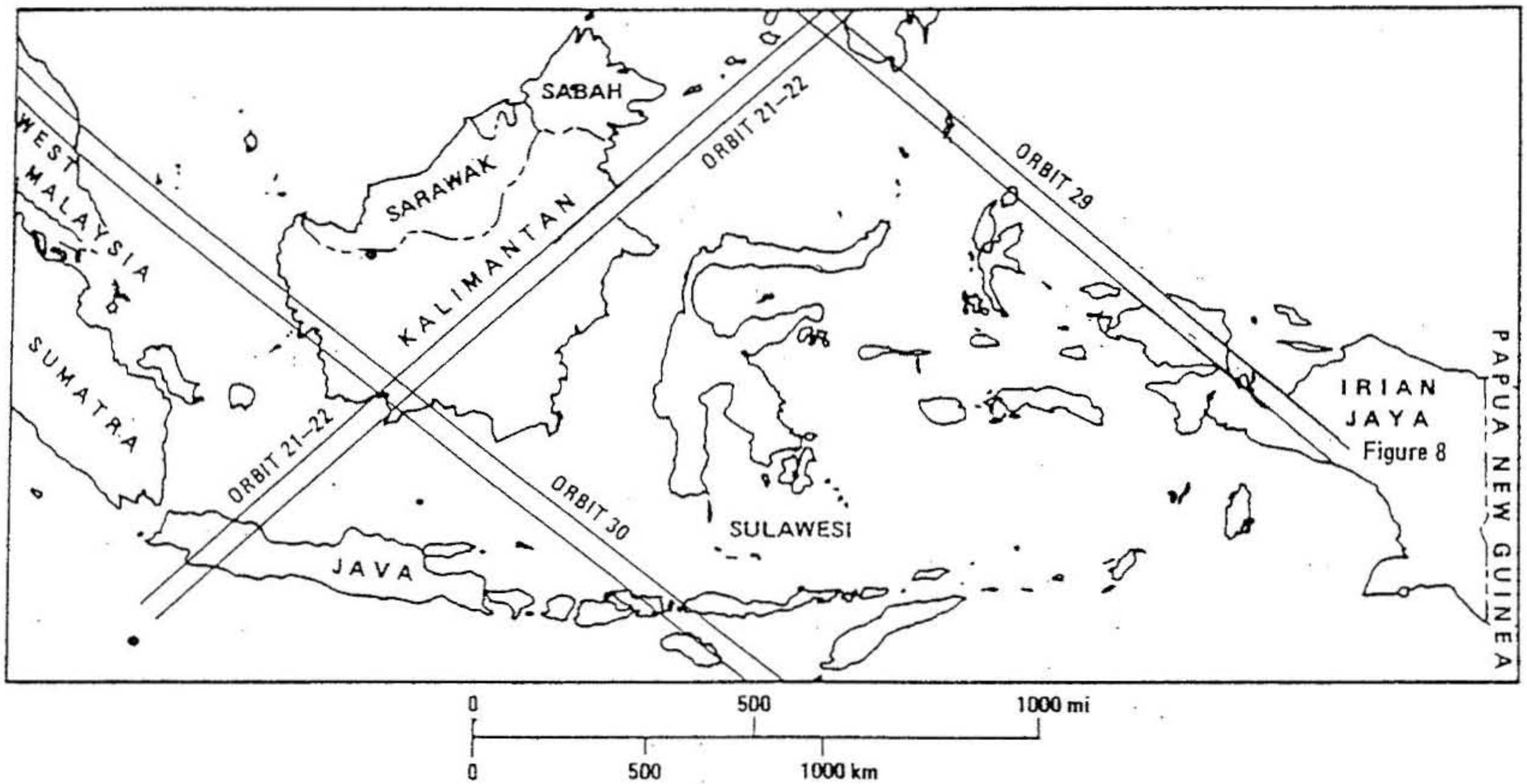


Figure 3 Index map of Indonesia showing SIR-A coverage (from Sabins, 1983).

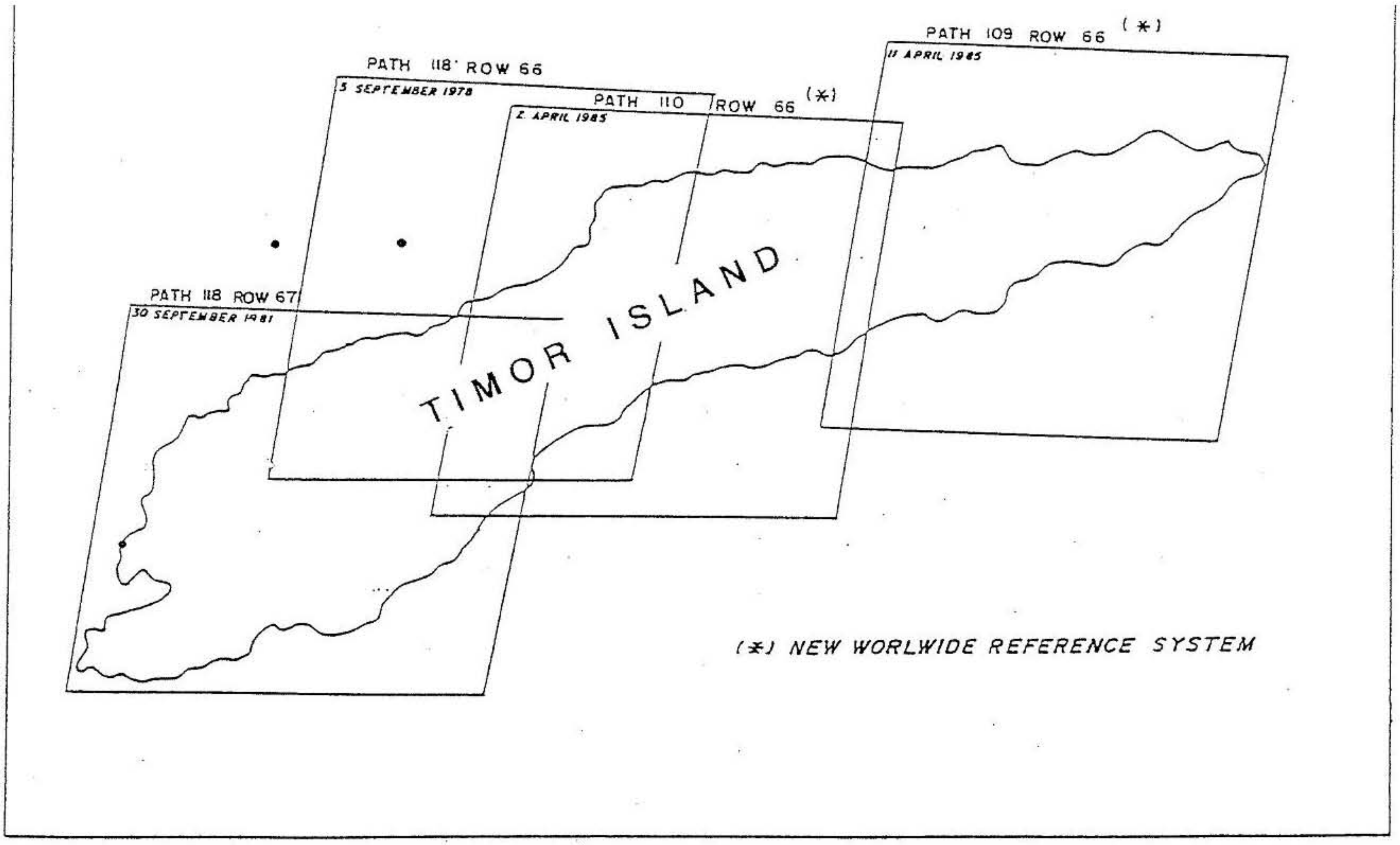


Figure 4 Landsat coverage of Timor Island (from PERTAMINA and LIPI, 1987).

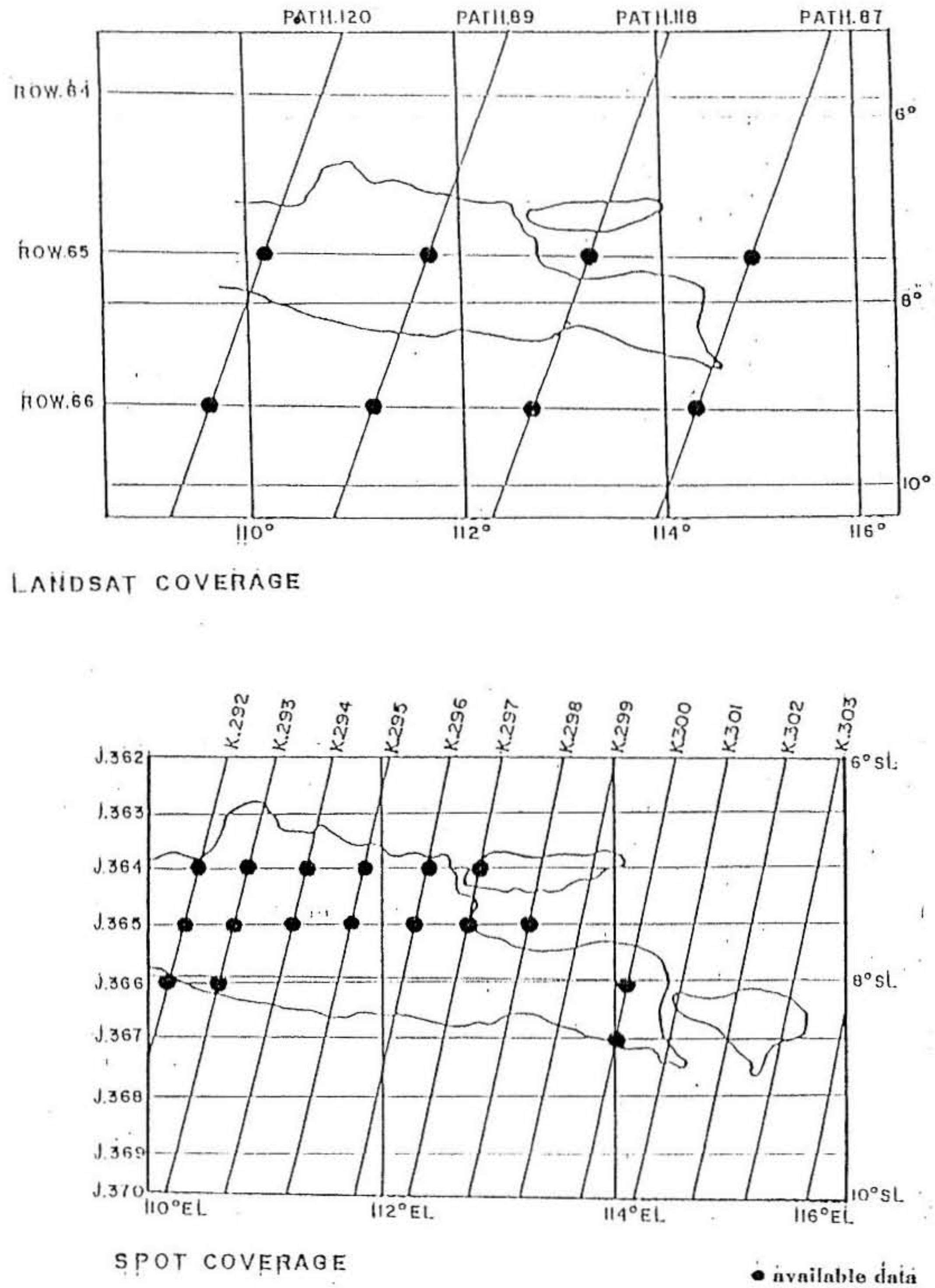


Figure 5 Landsat and SPOT coverages of Eastern Java (from PERTAMINA and LIPI, 1989).

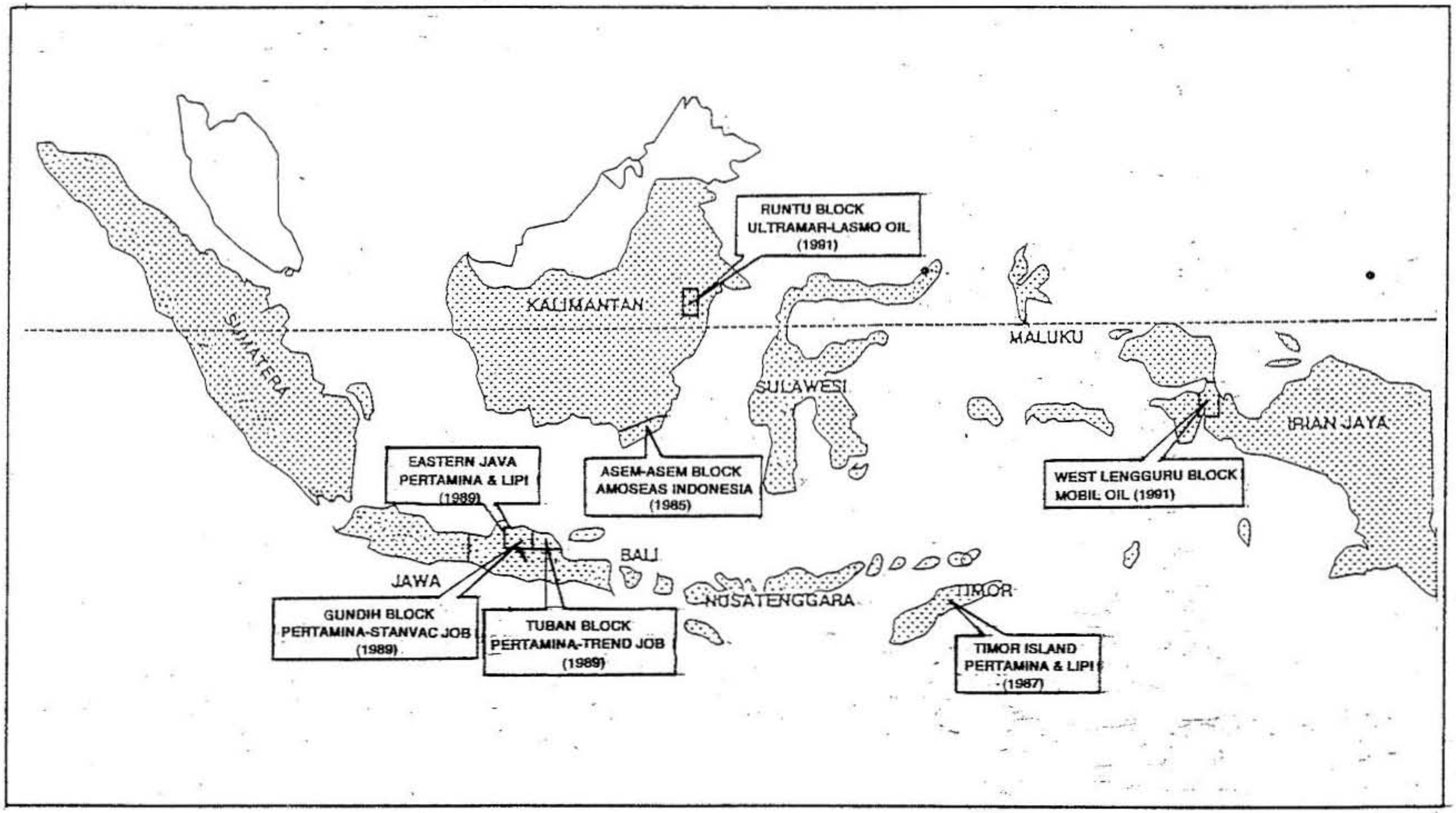


Figure 6 Location area of several remote sensing surveys in Indonesia.