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SIR-A VIEWS OUR ENVIRONMENT
An Experiment in the Batu Angkal Area, West Kalimantan, Indonesia

by
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ABSTRACT

Cloud cover is a serious problem for remote sensing in Indonesia. Some areas, around 10% to 20% of the land territory, are almost never cloud-free. The only system of remote sensing capable of overcoming cloud cover problem is that applying microwave energy. This article deals with a radar system being operated by the Columbia shuttle imaging radar A in 1981 in the Batu Angkal area, West Kalimantan, Indonesia. The choice of the study area is due to the availability of collateral material such as topographic map, land use map, and false color photographs.

The study is aimed at learning the interpretability of SIR-A image of 1:500,000 which is blown up to 1:250,000 for the study of the.environment of this area. The method used in the identification of environment is applying the physical characteristics of objects (tone, texture, shape, size, direction in relation to the illumination, surface roughness, and dielectric constant) to trace it.

The discernable elements of the environment of the study area are listed sequentially based on the ease of identificaiton: rivers and dissected hills, unpalnd forest and lowland forest, wetfields, and

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road and settlement.

Factors affecting the ease of identification are mainly tonal contrast, shape, size, surface roughness, direction in relation to the illumination, and dielectric constant. Due to the future availability of SIR-B image of Kalimantan, further study is recommended.

INTRODUCTION

Remote sensing has developed enormously during the last three decades. While the development of photographic remote sensing has probably reached its peak, the other systems are being developed. Differing from the former which uses the visible light (0.4μm—0.7μm) and its extention (near ultraviolet of 0.3μm—0.4μm and near infrared of 0.7μm—0.9μm), the latter uses the visible light and its extention, the thermal energy of 3.5μm—5.5μm, 8μm—14μm, and around 18μm, and the microwave spectrum with a wavelength of 1mm—100cm.

The flight mission using the visible light and its extention can be operated only in daytime under good weather condition. The thermal system is a little bit better regarding the time of operation because it can be operated in day and night time. Still good weather is a prerequisite for these two systems. No wonder that remote sensing data are lacking for some areas of Indonesia which are covered by cloud almost all the time, such as some parts of Sumatra, Kalimantan, Sulawesi, and Irian Jaya. It is for this reason that the systematic photography carried out by the Government of Indonesia has not been completed up to now, although the flight mission started in the second half of the 1970's. Around 10% to 20% of the whole land territory is still left blank. The problem of cloud cover is more serious for the land satellite or Landsat system because atmospheric attenuation is a function to distance. The altitude of Landsat is ca. 60 to 100 times higher than the medium altitude aircraft (9km—15km). The problem of cloud cover is accordingly more severe. In such condition, a remote sensing system which can be operated in all weather conditions is highly needed. The only system which fulfills this need is remote sensing which uses the microwave spectrum of the electromagnetic energy.

There are two types of microwave remote sensing: passive and active. The passive type uses natural energy and the active one uses energy which is generated in the sensing vehicle or platform. the passive microwave sensing is called 'microwave', while the active one is called 'radar'. The latter is much more widely used than the former.

This article deals with a preliminary study on the interpretability of SIR-A image for environmental analysis. It is aimed as a preparation for the probable use of the forthcoming SIR-B image of much larger coverage of Kalimantan area.

RADAR SYSTEM

Radar is an acronym of Radio Detection And Ranging. It was developed in the 1930's to detect the presence and location of ships and airplanes. The shortest radar wavelength is about 15,000 times as much as the longest visible light wavelength. Three point are worth mentioning for the radar system. i.e.: (1) advantages of radar system, (2) characteristics of radar imagery, and (3) type of radar imagary.

Advantages of a Radar System

Paine (1981) identifies six advantages of a radar system, four of which are: (a) all-weather capability, (b) long lateral coverage, (c) enhanced geologic features, and (d) night-time capability.

All-Weather Capability

Differing from the other remote sensing systems, the radar system can be operated in day and night time under all weather condition. The microwave energy can penetrate heavy cloud, even rain when L band of 23 cm wavelength or longer is used. The ability to penetrate cloud and rain is greater for the longer wavelength. Various bands which are used in the radar system are presented in Table 1.

Long Lateral Coverage

Because the radar illumination is directed obliquely to the side of the platform, it has the capability to image distant areas. Being operated from an aircraft, it is possible to image an area which is located 50 km or farther from the nadir line. It is an advantage for military purpose because the flight mission to detect enemy's territory can be carried out away from the enemy.

Enhancement of Geologic Features

The oblique illumination of relief features in the radar system causes a shadow effect that enhances topographic features of geologic significance, such as faults, fractures, and lineaments.

Night Time Capability

The active microwave system is not dependent on natural energy and hence it is advantageous for high lattitude areas especially in winter when the night is longer than the day-time.

TABLE 1. RADAR BANDS AND ITS WAVELENGTH

BAND	WAVELENGTH (CM)
Ka	0.8— 1.1
K	1.1— 1.7
Ku	1.7— 2.4
X	2.4— 3.8
C	3.8— 7.5
S	7.5— 15.0
L	15.0— 30.0
P	30.0—100.0

Source: Sabins (1978).

Characteristics of Radar Imagery

There are three points which will be discussed briefly in this section, i.e.: (a) radar operation, (b) resolution, and (c) interaction between energy and objects.

Radar Operation

As has been stated earlier, the radar system generates its own energy. The energy is radiated by an antenna with fixed position or look direction. It is directed perpendicular to the line of flight. The term 'Side Looking Airbone Radar' or 'SLAR' is due to the side looking direction.

The energy pulse in the radar system is radiated by the antenna, hits objects on the ground, and is reflected or back-scattered to the antenna. Because the transmission occurs only for brief periods of time (measured in microseconds), the antenna acts both as the transmitter and the receiver of the energy pulse. The antenna is switched from a transmitter to a receiver mode by a synchronizer switch (Lillesand and Kiefer, 1979). Some terminologies in relation to the direction of flight, the direction of illumination, and the range are presented in Figure 1.

Resolution

There are two types of resolution in the radar system, azimuth resolution

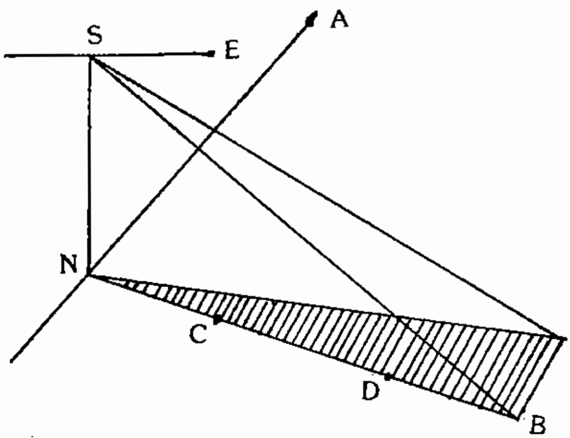

Figure 1. Radar System Terminology

Note:
S = platform (and sensor), N = nadir point, NA = flight line/azimuth direction, SB = slant range, NB = ground range which can be differentiated into near range (NC) and far range (ND), ESB = depression angle, illuminated area = antenna beamwidth.
(Lillesand and Kiefer, 1979; Paine, 1981).

and range resolution. Azimuth resolution is the smallest distance or object in the direction of flight, which can be recorded by radar system. It is also called along-track resolution. Range resolution or across-track resolution is the smallest distance or object perpendicular to the direction of flight which can be recorded by radar system.

Range resolution along a slant range equals half length of the pulse. If a 0.1 microsecond pulse length is 30 m, the slant range resolution is 15 m. A distance of 15 m or longer will be imaged by the radar system in this example. The slant resolution will not change in its distance from the aircraft. The ground range resolution, however, does change with distance from the aircraft. It varies inversely with cosine of the depression angle and it can be calculated by dividing the slant range distance by the cosine of the depression angle. If in our example the depression angle is 35°, the cosine will be 0.819 and the ground range resolution 18.3 m (Paine, 1981).

Lillesand and Kiefer (1979) stated that the ground range resolution can be computed by the following formula:

$$R = \frac{c\pi}{2 \cos \alpha} \quad \ldots\ldots \quad (1)$$

Where: R = ground range resolution
c = speed of light, 3×10^8 m/second
π = period of transmitting the radar pulse, in microsecond
α = depression angle.

Formula 1 indicates that the ground range resolution varies inversely with cosine of the depression angle. The finer ground resolution is achieved by bigger cos Θ, or smaller depression angle, the smaller depression angle means farther ground range. In other words, the ground range resolution in the far range is better or finer than that in the near range.

Azimuth resolution is determined by the angular beamwidth of the antenna and the ground range. Object AB at point 2 (Figure 2) cannot be resolved (imaged separately) because it is located in one antenna beamwidth, but it can be resolved well at point 1 or ground range 1.

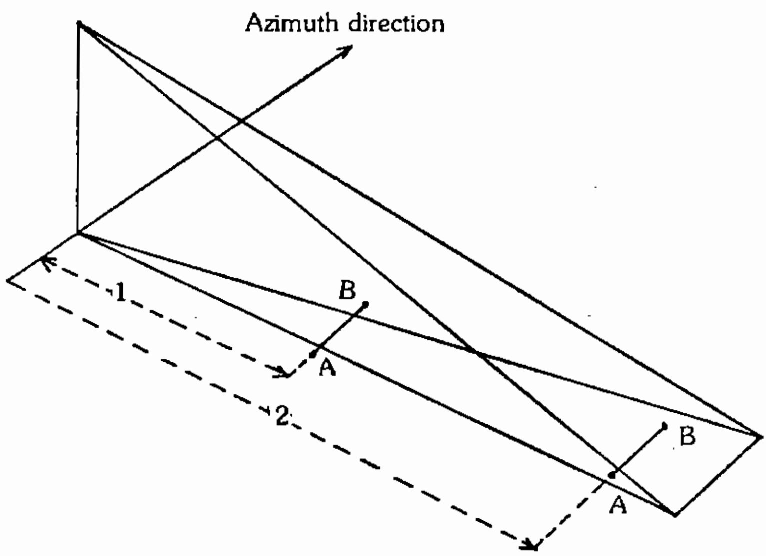

Figure 2. Azimuth Resolution in the Near Range and in the Far Range (Paine, 1981).

According to Lillesand and Kiefer (1979), the azimuth resolution can be computed by the following formula:

$$R_a = GR.\beta \qquad (2)$$

Where: R_a = azimuth resolution
GR = ground range
β = angular beamwidth of the antenna.

The beamwidth of the antenna is presented in Formula 3:

$$\beta = \frac{\lambda}{L} \qquad (3)$$

Where: λ = wavelength of the transmitted pulse
L = length of the antenna.

Formula 2 and Formula 3 indicate that the azimuth resolution varies inversely with the antenna length. The finer resolution is achieved by the longer antenna. It is difficult, however, to fix the long antenna under the sensing vehicle. The antenna is then synthetically made, meaning a shorter antenna which is effective for a longer one. An antenna of 2 m long can be made effective as long as a 600 m real antenna. The radar system using the real antenna is called 'real aperture' or 'brute force' system. The other one is called 'synthetic aperture' or 'coherent' system (Lillesand and Kiefer, 1979).

Interaction between Energy and Object

The interaction between radar energy and objects on the ground is influenced by five factors, i.e.: polarization, wavelength, side-lighted character of relief features, surface roughness, and electrical characteristics.

Radar signals can be transmitted and/or reflected in different modes of polarization. The signal can be filtered in such a way that its electrical wave vibrations are restricted to a single plane perpendicular to the direction of wave propagation. The radar signal can be transmitted horizontally and reflected horizontally (HH) or transmitted horizontally and reflected vertically (HV). In the same manner, radar imagery can be VV and VH types. The mode of signal polarization influences the appearance of objects in the resulted radar imagery. HH radar imagery is better for vegetation distinction than HV radar imagery (Lillesand and Kiefer, 1979). For building detection, HV type is the best, VH and HH are of intermediate capability, and VV type is the worst (Lewis, 1973).

Radar system can be operated at different wavelength. The shorter wavelength is better in terms of ground resolution, while the longer wavelength is better in terms of cloud cover penetrability. It is due to the quantum or photon theory the author states that the photon energy varies inversely with wavelength (Lillesand and Kiefer, 1979). Because the greater wavelength penetrates cloud cover. weather imaging is generally carried out using shorter wavelength.

Terrain sloping towards the radar sensor reflects more radar signal than that sloping away from the sensor. It is due to the fact that local variation in terrain slope causes varying angles of signal incidence. The incident angle is the angle between an impinging radar beam and a line drawn perpendicular to the surface of the ground. The reflected signal tends to increase when the incident angles decreases.

Surface roughness influences greatly the reflected radar signal. The rouhgness of an object's surface represents its relief variation in relation to the wavelength of the reflected energy. Surfaces with roughness equal to or greater than the radar wavelength appears rough and are called 'diffuse reflectors'. It scatters the incident energy, part of which is backscattered to the radar sensor. Objects with surface roughness much less than the radar wavelength appear smooth and are called 'specular reflectors'. It reflects the incident energy away from the sensor so that it looks dark in the radar imagery. A very high return occurs when the incident angle hit a 'corner reflector' (Figure 3).

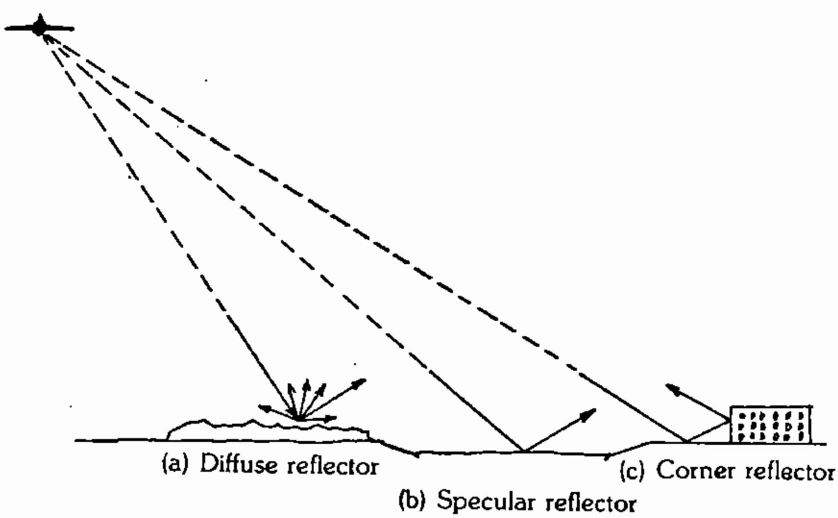

Figure 3. Radar Reflection from various Surfaces.
(Lillesand and Kiefer, 1979).

The electrical characteristics of terrain features also determine the intensity of radar reflection. One parameter for the reflectivity and conductivity of various materials is 'dielectric constant'. In the microwave spectrum, most natural materials have a dielectric constant in the range of three to eight when dry. Water has a dielectric constant of about 80. Consequently, the presence of moisture in soil or vegetation can significantly increase radar reflectivity (Lillesand and Kiefer, 1979).

Types of Radar Imagery

The early form of radar imagery is the 'plan position indicator' (PPI) radar. PPI display is created by a rotating antenna which images continously updated plan view map of objects surrounding the rotating antenna. PPI systems are used in weather forcasting, air traffic control, and navigation (Lillesand and Kiefer, 1979).

Radar system can be differentiated based on the platform into airborne system and spaceborne system. As has been stated earlier, the airborne system consists of SLAR and SAR, each of which can be differentiated further based on the wavelength used, such as X band, L band, or K band radar. Besides, it can also be differentiated based on the transmitted and reflected polarization, such as HH, HV, VV, or VH radar.

The spaceborne radar consists of 'Sea satellite' or 'Seasat' radar and 'Shuttle imaging radar' or 'SIR'. The Seasat radar is a SAR type. Shuttle imaging radar can be divided into SIR-A and SIR-B types. Seasat SAR was operated onboard the Seasat in 1978, SIR-A was operated onboard the Columbia space shuttle in 1981 and SIR-B in 1984.

SHUTTLE IMAGING RADAR-A

The Columbia space shuttle was launched in November 12, 1981 by NASA. The spacecraft carried its first scientific payload, part of which was the SIR-A system. The SIR-A experiment resulted in a radar of SAR imagery type covering about 10.000.000 sq.km. Each SIR-A image covers an area of 50 km wide and 100 km long (Ford *et al.*, 1983). The SIR-A coverage is presented in Figure 4 and the SIR-A system characteristics in Table 2.

There are three notable characteristics of SIR-A imagery based on Table 1, i.e.: (1) it can overcome cloud cover and rain because it uses L band radar of 23.5 cm, (2) the transmitted and the reflected signals are polarized horizontally, and (3) the ground resolution is 40 m along-track and 40 m across-track. It is not

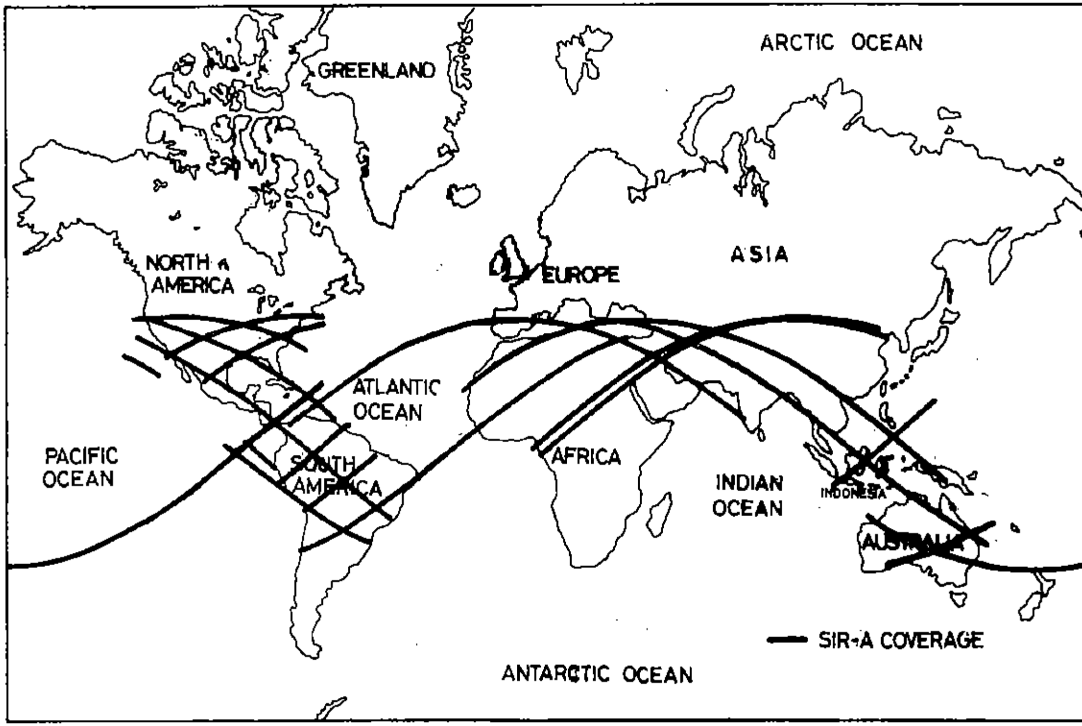

Figure 4. Global Coverage of SIR-A Image
Source: Ford *et al.* (1983).

TABLE 2. SIR-A SYSTEM CHARACTERISTICS

Parameter	Characteristics
Orbit	
Altitude	259 km
Inclination	38°
Radar	
Frequency	1.278 GHz
Wavelength	23.5 cm
System bandwith	6 MHz
Transmit pulse length	30.4 us
Pulse repetition frequency	1,464 to 1,824 Hz
Transmitted peak power	1000 W
Time-bandwith product	182
Polarization	HH
Antenna	
Dimension	9.4 m x 2.16 m
Look angle	47° ± 3°
Incident angle	50° ± 3°
Swath width	50 km
Resolution	40 m x 40 m
Data recording	Onboard: optical
Signal correlation	Optical

Source: Ford *et al.* (1983).

a fine ground resolution, but it is finer than the ground resolution of MSS Landsat.

SIR-A IMAGE OF THE STUDY AREA

The study was carried out in the Batu Angkal area of Ketapang Regency, the Province of West Kalimantan, Indonesia (Figure 5). This area extends ca. 400 sq.km.. It is covered by a part of SIR-A image series covering parts of North Australia, East Nusatenggara, South and West Kalimantan, Thailand, Burma, India, Pakistan, Italy, and Spain. The study area is chosen due to the availability of

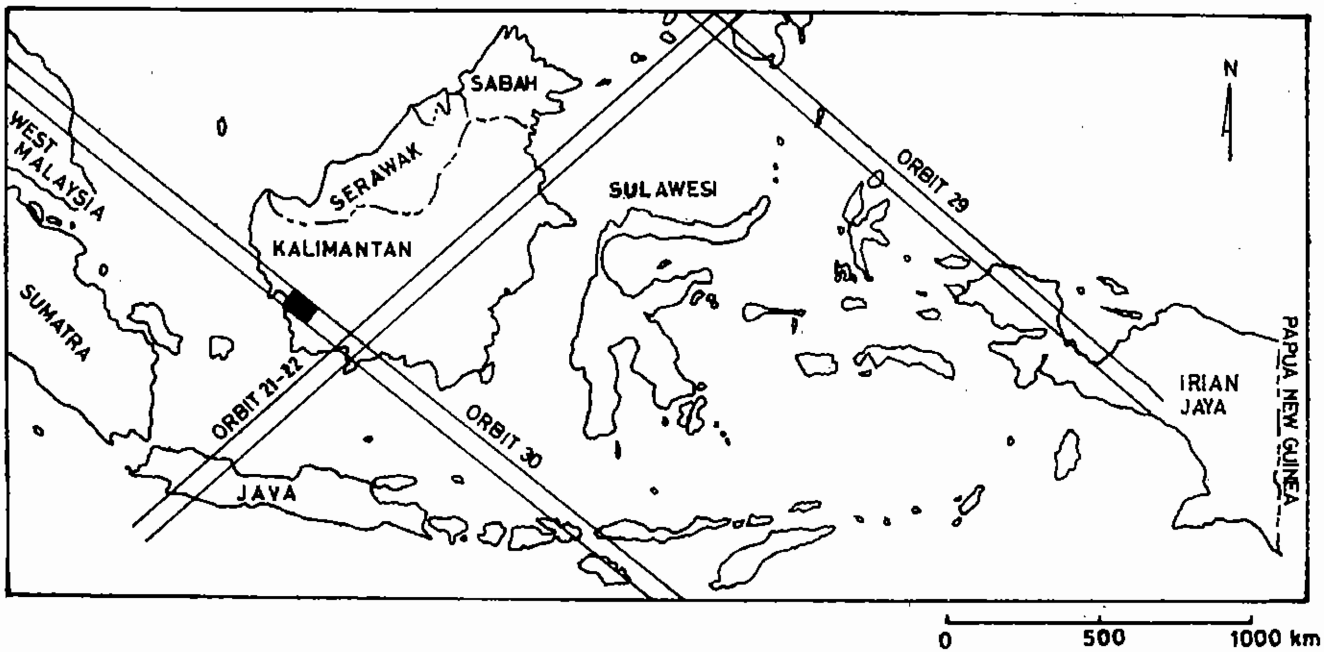

Figure 5. Location of the Study Area

Source: Sabins (1983).

the SIR-A image, topographic map of 1:250,000, land use map of 1:200,000, and color infrared photograph of 1:60.000.

As viewed from the sharpness of features presented by the image the quality of the SIR-A image used in this study is fairly good. The study area is located more or less in the central part of the frame, the information of which is not noted on the edge of the respective image (Figure 6).

INTERPRETATION OF THE ENVIRONMENT

To deal with interpretation of environment, three points will be presented briefly, i.e.: (1) definition of environment, (2) method of interpretation, and (3) result of interpretation.

Definition of Environment

The living environment is the spatial entity with all objects, potentials, conditions and living organisms, including man and his behaviour, which influence the continuance of the life and welfare of man and other living organisms (Office of the Ministry of State for Population and Environment, 1982).

From this definition, living environment or environment means the overall condition which surrounds and influences human life at any space on the earth surface. It embraces a wide area of elements including man with his ability and behaviour. Lithosphere, hydrosphere, atmosphere, biosphere, and anthroposphere are all our environment. The environment in this study is limited to those elements discernable on the SIR-A imagery, or, identifiable through the discernable objects or phenomena.

Method of Interpretation

The interpretation of the environment on the SIR-A image is carried out by taking the radar system and the characteristics of objects into account. The most important point concerning the radar system of SIR-A image is the wavelength used (23.5 cm) and the polarization (HH). As far as the characteristics of objects are concerned, spectral and spatial characteristics are used to identify objects presented by the SIR-A image. The spectral characteristics are presented by the grey-tone, while the spatial characteristics are presented by shape, size, shadow, texture, pattern, site, and surface roughness.

Because terrain sloping toward the radar antenna returns much more radar signals than that sloping away, slope is also taken into consideration in the interpretation. The ground range is taken into account as well. because the ground range resolution is not the same in the far and the near range.

Result of the Interpretation

A river 40 m to 70 m wide can be identified quite easily on the SIR-A image, regardless the range and the angle towards the range direction. It appears in a very dark tone because water surface acts as specular reflector. Besides, the spatial characteristics such as the long and irregular shape and also the fine texture cause the identification to be much easier.

A tributary of around 20 m wide can be identified with very dareful examination. It has a faintly dark grey tone. Its narrow water surface does not have sufficient opportunity to receive radar signals because it is covered by the dense vegetation, particularly where the tributary makes an angle towards the range direction. For those running parallel to the range direction, the opportunity to receive radar signal is greater so that it appears a little bit better.

A dissected hill with ridge leaning at an angle of about 45° against the range direction can be quite readily identified as well. It is due to the fact that slope facing the radar sensor looks bright, while the slope facing away the sensor looks dark. The alternating bright and dark tone is an indication of the rough topography.

The upland forest appears in a bright tone because of two reasons. First, the moderately rough texture of the forest causes it to be diffuse reflector. The roughness of the forest canopy is much more than 23.5 cm, the wavelength of the L band used for SIR-A image. The second is that the bright tone is enhanced by the slopes facing the radar sensor. The ground range does not influence this features much because it is an extensive feature.

The lowland forest is readily identified in the SIR-A image. The color infrared photographs indicate that part of the lowland forest occupies swampy areas. It is quite likely that the moisture content of the lowland forest increases the dielectric constant and hence causes the forest to appear in a very light tone.

A road 4 m to 6 m wide is not readily identified on the SIR-A image scaled to 1:500,000 which is blown up to 1:250,000, even with a very careful examination. It appears like a fine string in this image.

Wetfield of at least 20 ha is readily discernable in the SIR-A image. It appears dark due to the specular characteristics of water. Dry agricultural land, however, is not readily discernable. It is probably due to the fact that dry agricultural land is usually planted with crop coarser than rice, making only very

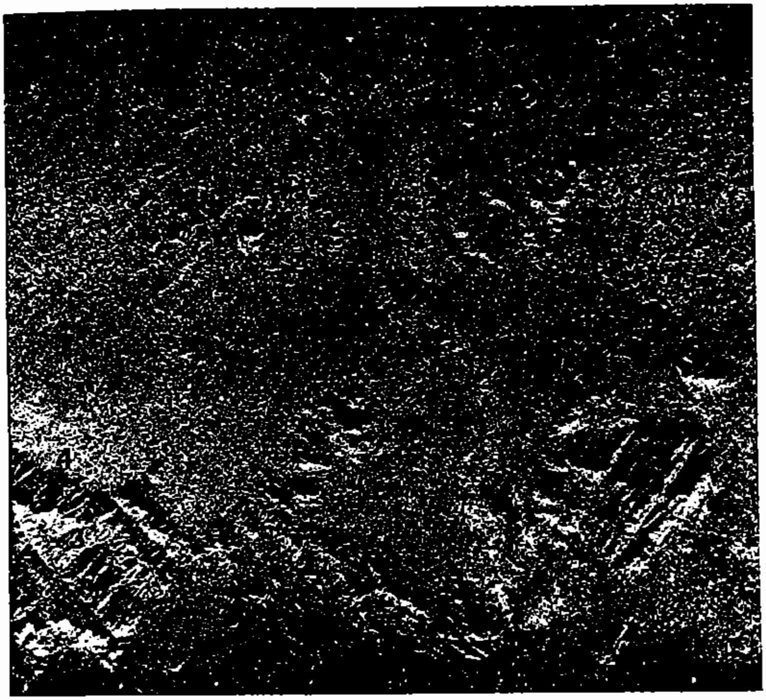

Figure 6. SIR-A Image of the Study Area and Its Interpretation

Note: It is reproduced from the original image, the scale of which is reduced into 1:300,000. This photograph is located at the central portion of the original frame.

small contrast in the area of shrub or bush.

A ribbon settlement with two parallel roads 60 m apart and 400 long can be identified with very careful examination on this image. The color aerial photographs indicate that the settlement is occupied by 78 dwelling houses, with a total area of some 2.4 ha, which is inhabited by some 400 people. A study carried out by Horler *et al.* (1980) of the United States proves that the settlement of less than 1,000 inhabitants is only 60% visible on X band radar image of 1:200,000, and only 40% visible on the same type of image scaled to 1:400,000. The spatial resolution on radar image using X band is better than that using L band radar because the wavelength of the former is shorter than the latter. Frankly speaking, the settlement of ca. 400 inhabitants is

TABLE 3. INTERPRETATION OF SIR-A IMAGE

Location	Tone	Texture	Shape	Size	Site	Direction	Range	Ease of Identification	Object
1	Dark	Smooth	Linear	40m—70m	—	—	Near — Far	1	River
2	Dark grey	Smooth	Linear	20m	—		Near	2—3	Tributary
3	White and dark grey	Rough	Circular		—	—	Far	1	Dissected hill
4	Light	Medium	—	—	Uphill	—	Far	1—2	Upland forest
5	Light	Medium	—	—	Lowland, partly swamp	—	Near — Far	1—2	Lowland forest
6	Dark grey	Smooth	Linear	± 6 m	—		Medium — Near	3	Road
7	Dark	Smooth	Circular-Rectangular	20 ha	Lowland	—	Near	2	Wetfield
8	Light grey	Medium	Elongated	± 2.4 ha	River side		Near	3	Settlement

Explanation

Direction:
- ▬ parallel
- ▬ make an angle to the range direction
- ▬ perpendicular

Ease of identification
1 ▬ very easily identified
2 ▬ fairly easy to identify
3 ▬ difficult to identify

visible on this image because it is first seen on the airphotos of 1:60.000 by the interpreter. Without the airphotos, it will be hard to identify. With the use of the SIR-B image having azimuth resolution of 25 m and range resolution between 17 m to 50 m, it may be more readily discernable.

ANALYSIS OF THE RESULT

Based on Table 3 the most readily discernable features on the SIR-A image of the study area are rivers and dissected hills, regardless the range and the direction in relation to the range direction, or the direction of illumination. It stems from the fact that both features show great contrast to the background or the surrounding features. The river shows a great contrast because of its very dark tone and its linear features, whereas the dissected hills show a great contrast to the surroundings because of their alternating light and dark tones.

The second feature that is easily identified is upland and lowland forest. Again, it is mainly due to the great tonal contrast. Differing from the first features, the tonal contrast of the forest is a little bit smaller. Besides. the spatial aspect such as linear feature makes the identification easier.

Wetfields rank third in the ease of identification because of their smaller size as compared to that of the other features. Their water, which acts as specular reflector, however, enhances the tonal contrast.

Tributary streams rank fourth in the case of interpretation. It is mainly due to the narrow size of the channels and the water surface as well. Although water acts as specular reflector, the tributaries are hidden by dense vegetation in places where the river sourses do not run parallel to the range direction.

The next and the most difficult features to identify are roads and settlement. Two reasons may explain this. First is the small size of the features and second is insufficient tonal contrast. especially for the road.

One notable thing is worth mentioning in this respect. The direction of linear features in relation to the direction of illumination affects greatly the ease of identification. It is particularly the case for narrow features. The range does not affect significantly the identification of the eight features. Furhter study should be carried out in this concern.

CONCLUSION AND RECOMMENDATION

For the Batu Angkal area, which is not well developed and the features of which are mostly of small size, not many data on the environment can be acquired through the SIR-A image scaled to 1:500,000 which is blown up to 1:250,000. The features sequentially mentioned according to the ease of identification, are river and dissected hill, upland forest and lowland forest, wetfield, tributary, road and settlement. The ease of identification of the features is affected greatly by the tonal contrast, texture, shape, size, site, and direction in relation to the direction of illumination.

The author are of the opinion that radar system of remote sensing will get more and more important in the future. It stems from the fact that some 20% of the Indonesian land territory is always covered by cloud, making other systems of remote sensing impossible. Besides, shuttle imaging radar system is going to be developed further. Differing from the available coverage of SIR-B images making only some strips of the Indonesian territory, a program has been set up to cover almost the whole area of East Kalimantan and South Kalimantan Provinces with SIR image in 1987. Accordingly, further study on the radar system in general and the shuttle imaging radar in particular, should be encouraged.

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