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APPLICATION OF NOAA SATELLITE DATA FOR CROP ASSESSMENT IN MALAYSIA

A Training Report on Satellite Assessment Methods

by

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PREFACE

The work described in this report represents the training activities of Mr. Tung Nam Ping and Muhammad Pilus Bin Zambri of the Malaysian Meteorological Service and Department of Agriculture, respectively, during the period May 13 through June 21, 1985. The training program was designed to familiarize the participants with data from the Advanced Very High Resolution Radiometer (AVHRR) on board the NOAA Polar-Orbiting Satellites and to provide insight on the application of this data for the operational Agroclimatic Assessment Programme in Malaysia. This report documents procedures used in training and includes findings and suggestions which may serve as reference for future work.

The enthusiasm, dedication and professionalism which Mr. Tung Nam Ping and Muhammad Pilus Bin Zambri showed during the training effort was stimulating and presented a challenge to the many staff members with whom they worked. Their training was carried out by the staff of the Climate Impact Assessment Division, Assessment and Information Services Center (AISC) in Washington, D.C and in Columbia, Missouri with assistance from the staff of the Cooperative Institute of Applied Meteorology at the University of Missouri. AISC is part of the National Environmental Satellite, Data, and Information Service (NESDIS), NOAA. The training was partially supported by funds from the U.S. Agency for International Development, Office of Foreign Disaster Assistance.

Clarence Sakamoto
Chief, Models Branch

EXECUTIVE SUMMARY

This report summarizes a six week training program on the application of NOAA satellite data for crop assessmnet. AVHRR channel 1 and channel 2 data from the NOAA Polar Orbiting Satellite are processed and stored on diskette for image analysis and interpretation on a personal microcomputer (PC). Hard copies of the image products were produced by photographing the high resolution color monitor. Examples are included in this report.

AVHRR channel 1 and channel 2 data are used in a combined form to take advantage of the differences in the data. Vegetation, for example, reflects more near infrared energy (channel 2) than visible energy (channel 1). Various vegetation indices produce a positive value for vegetation as contrasted against other Earth surface features which produce a near-zero or negative index.

These values are mapped into a two dimensional coordinate system to form an intensity, hue and saturation image. This image is enhanced using the Ambroziak Color Coordinate System for qualitative interpretation.

Image interpretation exercises carried out during the training program are included in Section 6. Field verification and additional practical experience are required to derive the maximum amount of information from the images. These images are normally used in a time series form to follow the growing condition and trend of crops.

A problem identified in using this satellite assessment tool in Malaysia is that most of the time the sky is cloudy. To overcome this problem, a weekly compositing technique is applied to coarse resolution polar stereographic (PSG) data. There is a need to apply similar compositing techniques to high resolution (HRPT or LAC) data to produce images for analysis which are more cloud free. The satellite assessment method

can be used to complement the Agroclimatic Impact Assessment Programme in Malaysia provided that the recommendations mentioned in Section 8 can be implemented.

ACKNOWLEDGEMENTS

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The training program was coordinated by Dr. Gary E. Johnson, Remote Sensing Scientist, NOAA. He conducted various lectures on vegetation assessment and remote sensing and shared his experience with the authors. His guidance and suggestions during the course of training are sincerely appreciated.

Mr. Russell Ambroziak, Chief of the Climate Impact Assessment Division, lectured on the principles of color science; this greatly facilitated understanding of the multispectral color enhanced image interpretation process using the IHS color scheme. Dr. Clarence Sakamoto, Chief of the Models Branch, lectured on the operational aspects of the agroclimatic impact assessment program and stressed that there is a need for integration of satellite data into this program. The authors wish to thank them for sacrificing their valuable time.

Thanks are also due to the following staff members for their valuable guidance and support:

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1. INTRODUCTION

Agricultural assessment is needed to help planners initiated to stabilize agricultural commodity prices due to fluctuation in agricultural production and cushion the consequences of acute food shortages due to drought, flood, pests and diseases. Remote sensing has long been viewed as a useful tool for providing valuable information concerning agriculture. Currently, Landsat imageries are used for agricultural assessment. Only recently scientists successfully extended the application of NOAA Polar Orbiting Satellite Data to agriculture. The combination of visible and near infrared data from the NOAA Satellite revealed valuable information on the growing condition of crops. The AVHRR data are used in two forms in the assessment procedure, multispectral color enhanced images and time series plots of satellite vegetation index. NOAA organized this six-week training course to transfer the latest remote sensing technology to Malaysia. The training program is part of the Agency for International Development's Office of Foreign Disaster Assistance disaster preparedness program.

This training concentrates on the development of the AVHRR image enhancement technique and the interpretation of the imagery. Training set examples developed during the training are included in this report. The knowledge and the latest technique acquired during the training will be used to complement the Malaysian Agroclimatic Impact Assessment Programme.

2. NOAA POLAR ORBITING SATELLITES

The NOAA polar orbiting satellites were designed primarily for meteorological applications. Currently there are two NOAA spacecraft in operation. One spacecraft is in a descending mode, crossing the equator at 0730 local time, the other in an ascending mode, crossing the equator at 1430 local time.

One of the instrument systems on board the NOAA satellites is the Advanced Very High Resolution Radiometer (AVHRR). The AVHRR sensors are sensitive in five spectral regions:

Channel 1	0.55-0.68 μm (visible)
Channel 2	0.73-1.10 μm (near infrared)
Channel 3	3.55-3.93 μm (infrared)
Channel 4	10.5-11.5 μm (thermal infrared)
Channel 5	11.5-12.5 μm (thermal infrared)

The spectral sensitivity of AVHRR channel 1 is similar to band 5 of the Landsat Multispectral Scanner (MSS) and AVHRR channel 2 is similar to Landsat MSS band 7. The Landsat data have been used extensively in monitoring vegetation.

The AVHRR has a ground resolution of 1.1 km at Nadir. The advantages of using NOAA satellite data for crop assessment are that it is available close to real-time and coverage is daily.

3. AVHRR DATA

The AVHRR data is digitized to ten-bit precision. The digitized data is transmitted from the NOAA satellite to the ground receiving station in real-time as High Resolution Picture Transmission (HRPT) data. The same set of AVHRR data is selectively recorded on board the satellite for subsequent playback as Local Area Coverage (LAC) data. A maximum of ten minutes of LAC data may be recorded per orbit. The LAC data include five spectral channels and have a spatial resolution of 1.1. x 1.1 km (Figure 1).

The processor on board the satellite also samples the real-time AVHRR data to produce reduced resolution Global Area Coverage (GAC) data. Four out of every five samples along the scan line are used to compute one average value, and the data from only every third scan line is processed. As a result, the spatial resolution of GAC data near the satellite subpoint is actually 4.0 km by 3.3 km, generally treated as 4 km resolution. All of the GAC data computed during a complete pass is recorded on board the satellite for transmission to earth on command.

The lowest resolution data produced is the Polar Stereographic (PSG) data. PSG data are produced on the ground by assigning the last GAC pixel value from a 4 x 4 grid to a PSG pixel. PSG data are mapped onto a standard polar-stereographic projection. The sampled PSG pixels vary in area according to latitude, ranging from 15 km (225 km^2) at the equator to 30 km (900 km^2) at the poles.

PSG DATA GENERATION

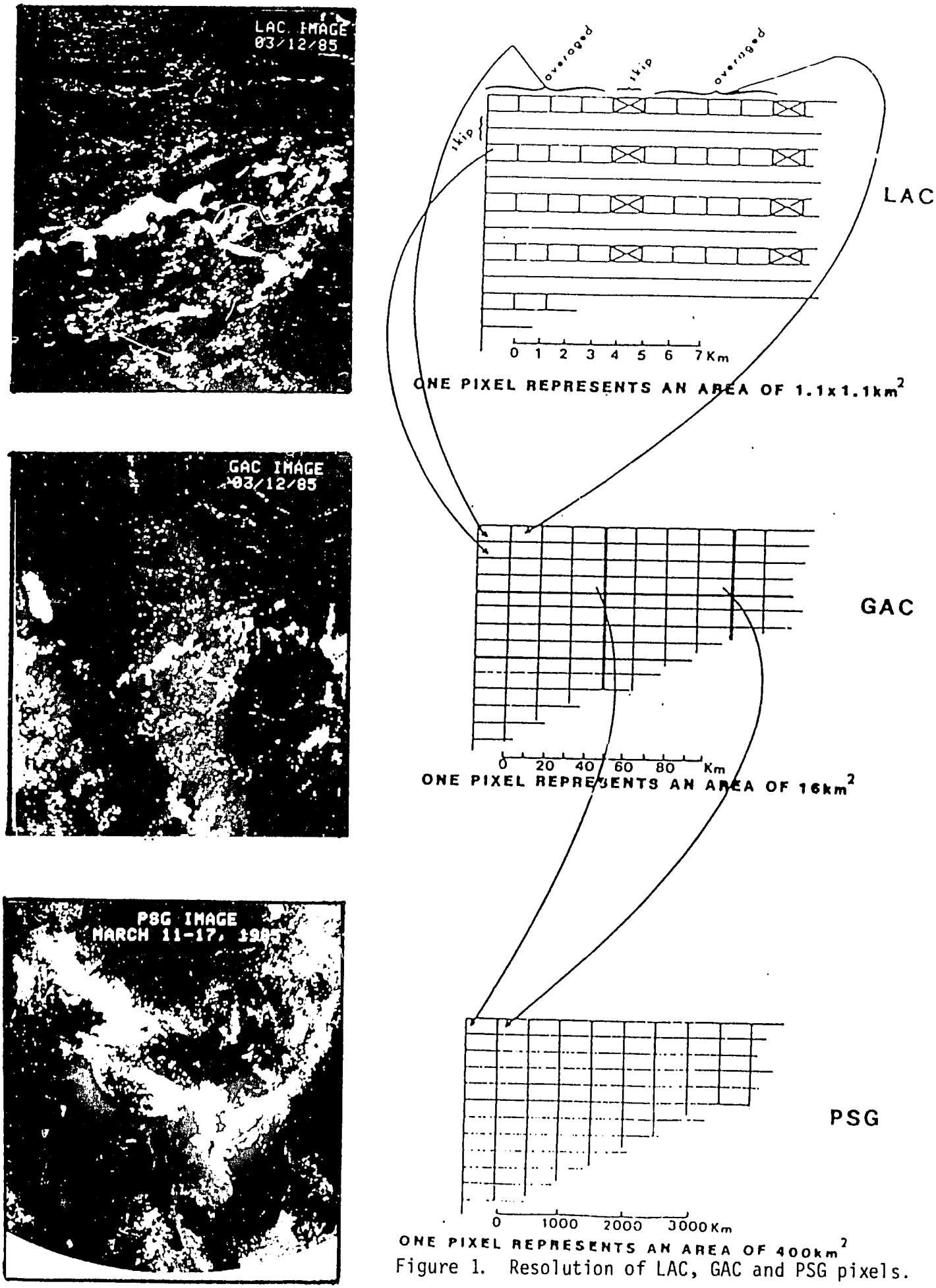


Figure 1. Resolution of LAC, GAC and PSG pixels.

4. VEGETATION INDEX

All plants reflect relatively more near infrared than visible sunlight because of the strong absorption of visible light by the chlorophyll present in the green leaves (Figure 2). Surface water reflects more visible light than near infrared light. Other things reflect nearly equal amounts of visible and infrared light. Because of these differential reflectance characteristics in the visible and infrared parts of the spectrum, a combination of channel 1 and 2 of the AVHRR sensor can be used to assess vegetation condition. Examples of combinations of channel 1 (CH1) and channel 2 (CH2) are:

Difference Vegetation Index	$DVI = CH2 - CH1$
Ratio Vegetation Index	$RVI = CH2/CH1$
Normalized Vegetation Index	$NVI = \frac{CH2 - CH1}{CH2 + CH1}$

Clouds, water and snow have slightly larger reflectances in the visible than in the near infrared so for these features NVI is slightly negative. Rock and bare soil have similar reflectances in these two bands so NVI approximates zero. In the vegetation scenes, NVI is positive; the higher values are associated with greater density and greenness of the plant canopy.

The vegetation index values can be computed and presented in two forms, spatial presentation and temporal presentation for crop assessment. In spatial presentation, the computed vegetation index values are plotted onto the corresponding pixel position to form an array. A color or grey level scale is used to show different vegetation conditions. In temporal presentation, the average weekly vegetation index values are plotted against time to form a time series plot of vegetation index for a particular region.

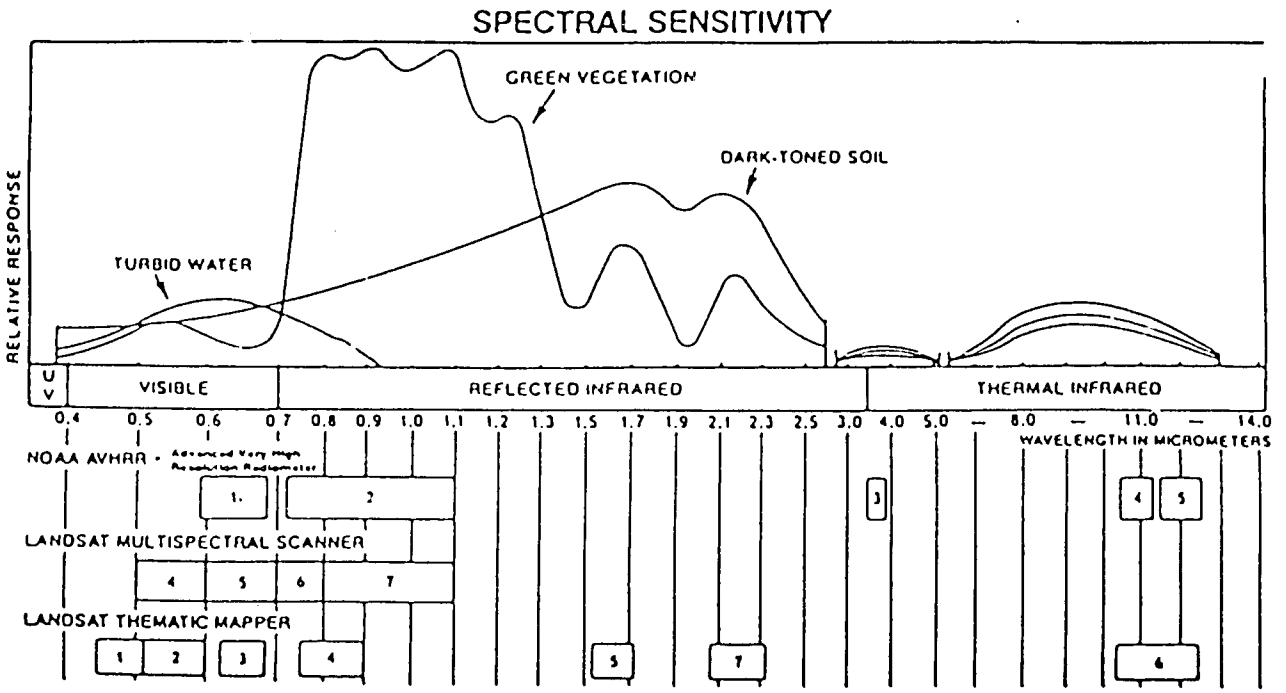


Figure 2. The Spectral Sensitivity of Three typical Land Cover Features as Related to Bands Sensed by Three Multispectral Systems.

These assessment products can be used to monitor crop growing conditions for the current growing season and also to compare the vegetation index of the current growing season with those from the previous years for a particular region. If a crop area looks worse this year than last year, it could be because the crops have been stressed or diseased, one crop in a multi-crop growing area was harvested, there may be standing water from excessive rains, or for other reasons. The data can be interpreted successfully only if the analyst is familiar with local agricultural practices.

One disadvantage of using satellite data for crop assessment in tropical regions is that most of the time the sky is cloudy. To overcome this problem, a weekly compositing algorithm is applied to the daily PSG data to

aid in removing clouds and large satellite look angles. In the composite data set, for each pixel location only the data for the day with the highest NVI is retained. This assumes that the most cloud-free pixel for the week is chosen. The only cloudy pixels in the composite are those which were cloudy every day. For crop assessment in tropical regions, full LAC resolution is better than PSG data because of increased spatial discrimination and the problem of cloud interference.

5. MULTISPECTRAL COLOR ENHANCED IMAGE

Earlier we have seen the mathematical combination of pixel magnitudes of channel 1 and channel 2 to create a vegetation index. Channel 1 and channel 2 images can also be combined to form a '2-dimensional' image. (Figure 3).

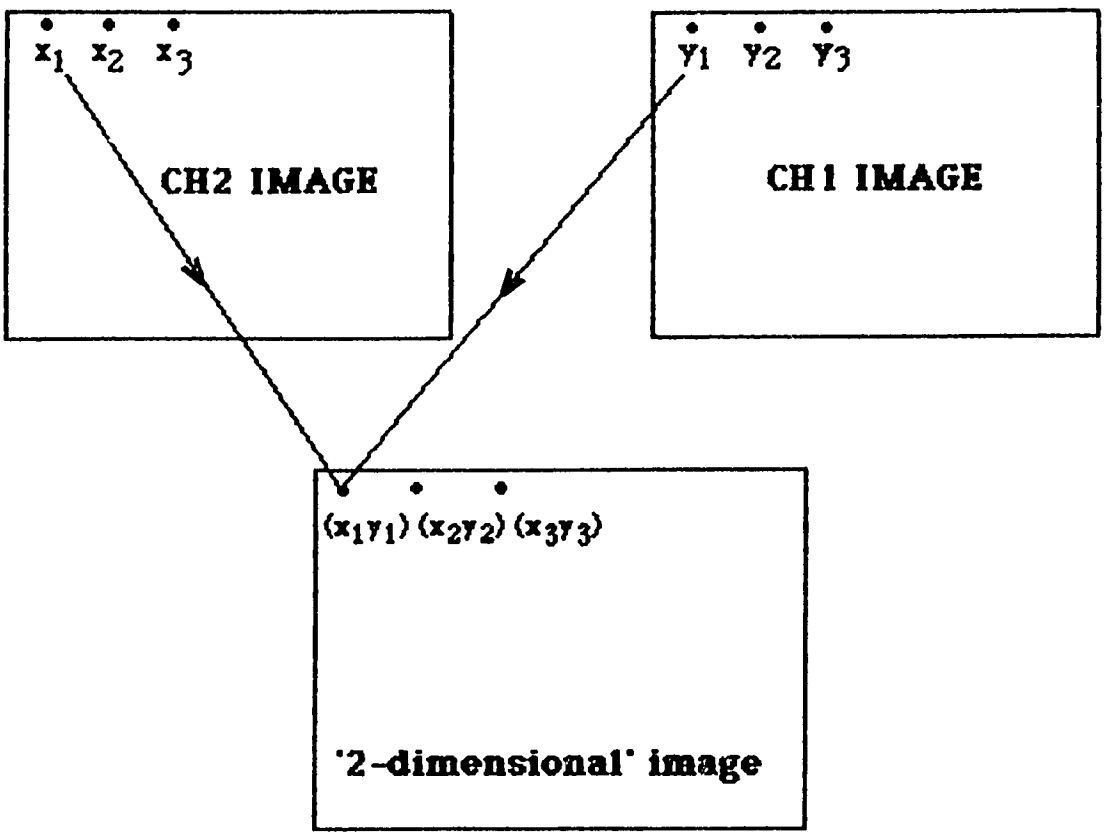


Figure 3. Mapping of CH1 and CH2 Pixels into Two-Dimensional Coordinate Pixels.

Informative and meaningful interpretation of the '2-dimensional' image requires a '2-dimensional' color coordinate system. The Ambroziak Color Coordinate System (ACCS), based on hue, intensity and saturation, was designed to meet this need. This system simplifies the task of

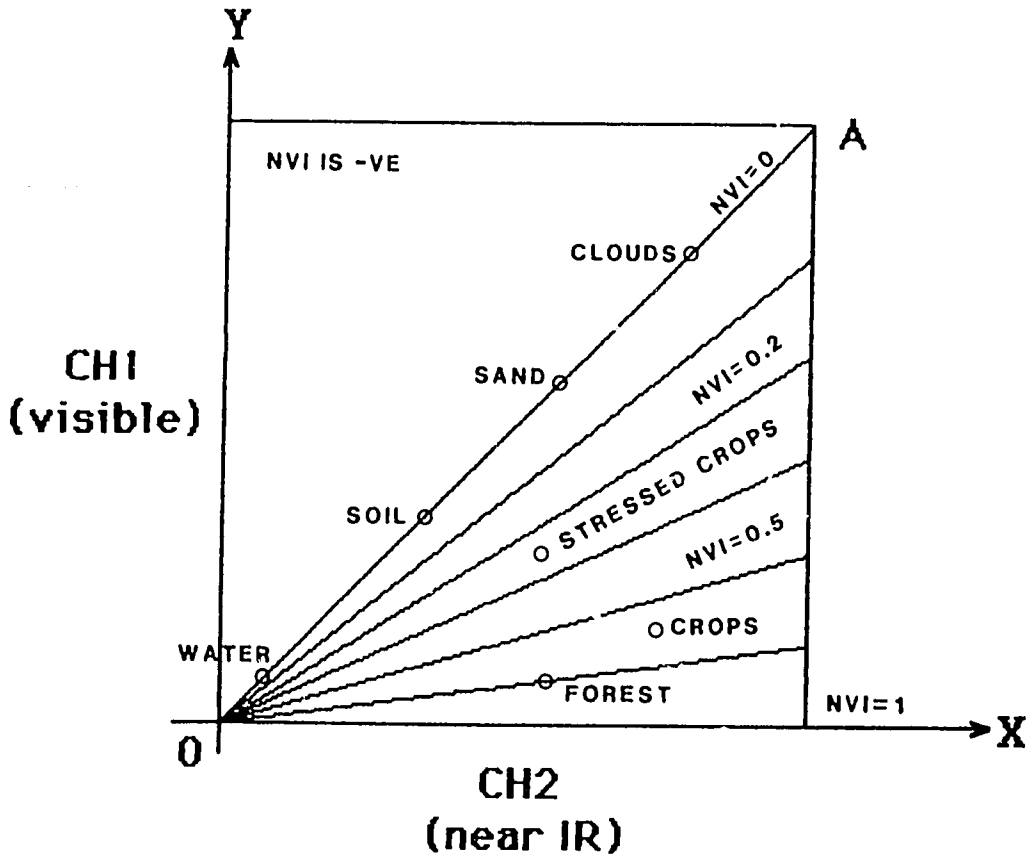


FIGURE 4: TARGETS PLOTTED AS A FUNCTION OF NVI.

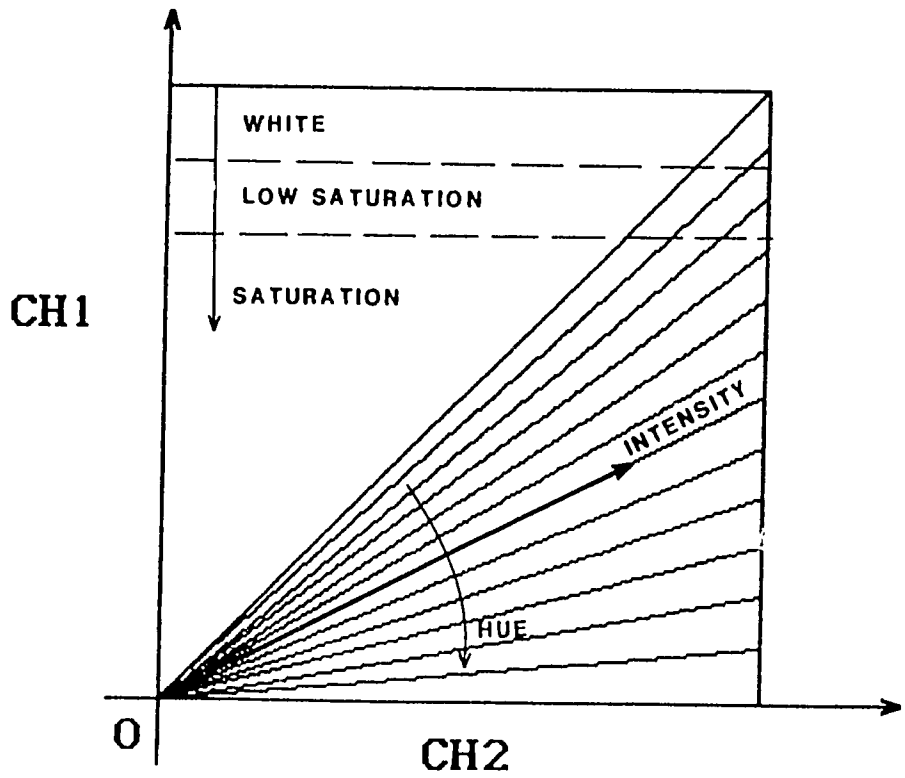


FIGURE 5: AMBROZIAK COLOR COORDINATE SYSTEM.

interpreting multispectral images by remapping the data into the hue, intensity and saturation color space (Figures 4-5).

On Figure 4, the Y axis represents the channel 1 albedo (visible) and the X axis represents the channel 2 albedo (near infrared). Clouds, bare soil, sand and water reflect almost equal amounts of visible and near infrared radiation, so values fall near the diagonal OA. Vegetation reflects more in the near infrared than in the visible, so values fall between OA and OX (i.e. NVI is positive). The greater the difference between the near IR and visible reflectances, the more biomass is present and the greater the Leaf Area Index (i.e., the greater the NVI). Vegetation of the same NVI will fall on the same diagonal. The area between OA and OX is divided into 17 wedges. Each wedge is assigned a different color or hue. Hue is the attribute of color preception denoted by blue, green, yellow, red, etc.

Intensity is used to distinguish between pixels having the same NVI. The higher the pixel values, the brighter the pixel. Take as an example features with NVI=0: water (with very low visible and near IR reflectances) appears black; bare wet soil (with slightly greater reflectances) appears pale dark red; sand (with still greater reflectances) appears medium bright red; and clouds (with very high reflectances) appear very bright red in the original ACCS.

Pixels with higher visible reflectances are assigned lower saturations. Saturation denotes the presence or absence of color or whiteness (e.g. as red becomes less saturated it appears pink, then finally white). As a result, bright, visible pixels, like clouds, have a lot of white, while dark visible pixels like water and lush vegetation have a deep rich hue.

By using the ACCS more information can easily be obtained from the image than by using traditional false color enhancements. An illustration of the use of the ACCS is given in the next section.

6. TRAINING SET EXAMPLES

These two sets developed during the training indicate that the AVHRR channel 1 and 2 data can be used to complement the crop assessment program in Malaysia.

TRAINING SET EXAMPLE 1

By using ACCS, the features mentioned in Table 1 can be identified. In Image 1, the white and grey scenes are clouds, the purple and black scenes are water, the cyan and green scenes (marked 1) are vegetation, the red and orange scenes (marked 2) are urban areas and bare soil.

Image 2 and image 3 give a closer look at the level II and level III features. The purple scene (3.2) is turbid water and the black scene (3.1) is clear water. The green scene (1.2) is forest, not very dense and poorly drained. The cyan scene (1.1.1) indicates plantation crops. The major crops in this area are oil palm, coconut and rubber. Delineation between each crop is not possible due to the low spatial resolution of the AVHRR. The brown scene (1.1.2) indicates young paddy field. This is a portion of the rice growing area. The rest of the area is covered by clouds. The low vegetation index of this paddy field is due to the muddy water surrounding the young paddy plants during the transplanting period.

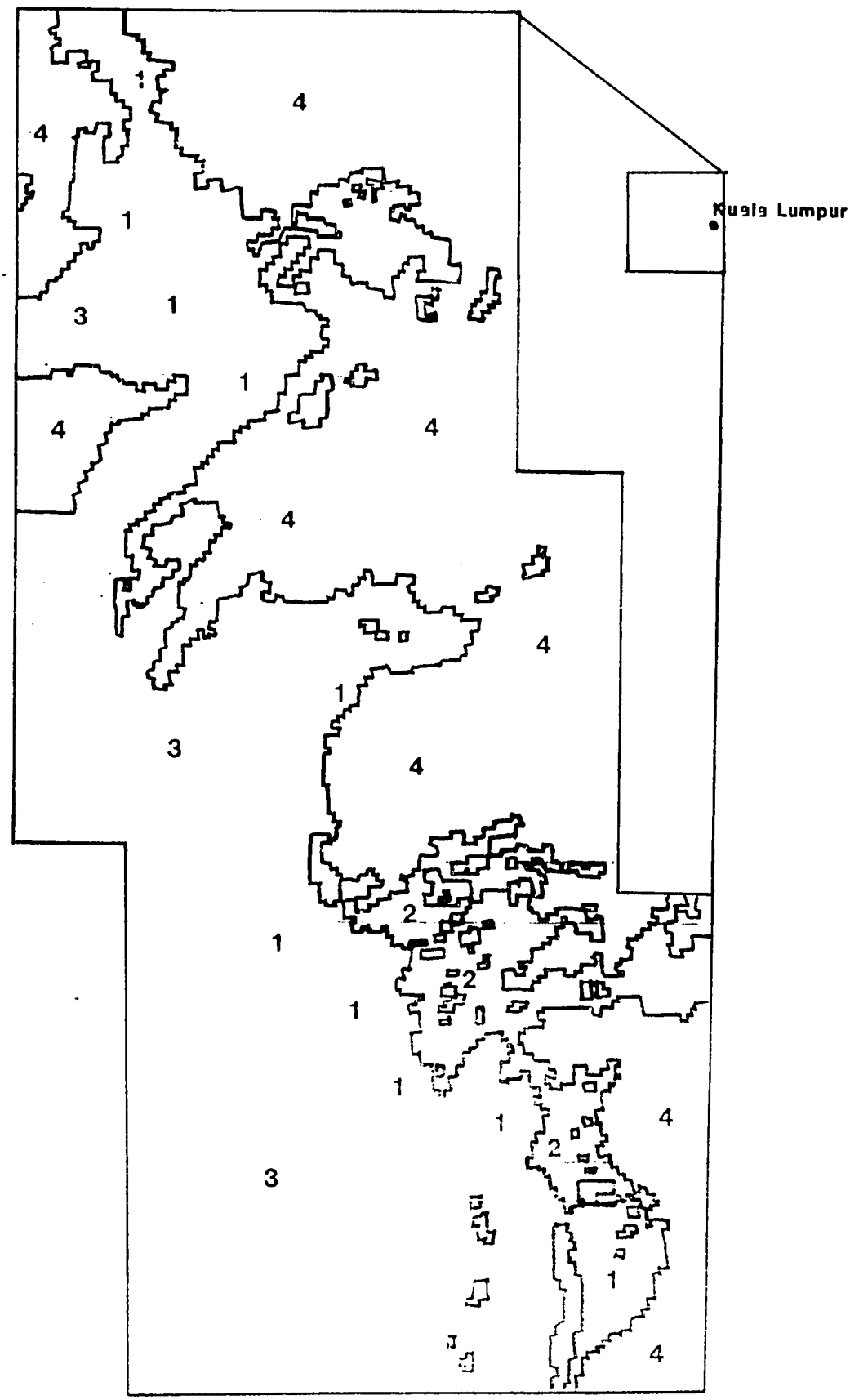
LEVEL I	LEVEL II	LEVEL III
1. Vegetation	1.1. Agricultural Land	1.1.1. Plantation Crops 1.1.2. Paddy Field
	1.2. Forest Land	
2. Urban Areas		
3. Water	3.1. Clear Water	
	3.2. Turbid Water	
4. Cloud Cover	4.1. Thick cloud layer	
	4.2. Thin cloud layer	
	4.3. Cloud shadow	

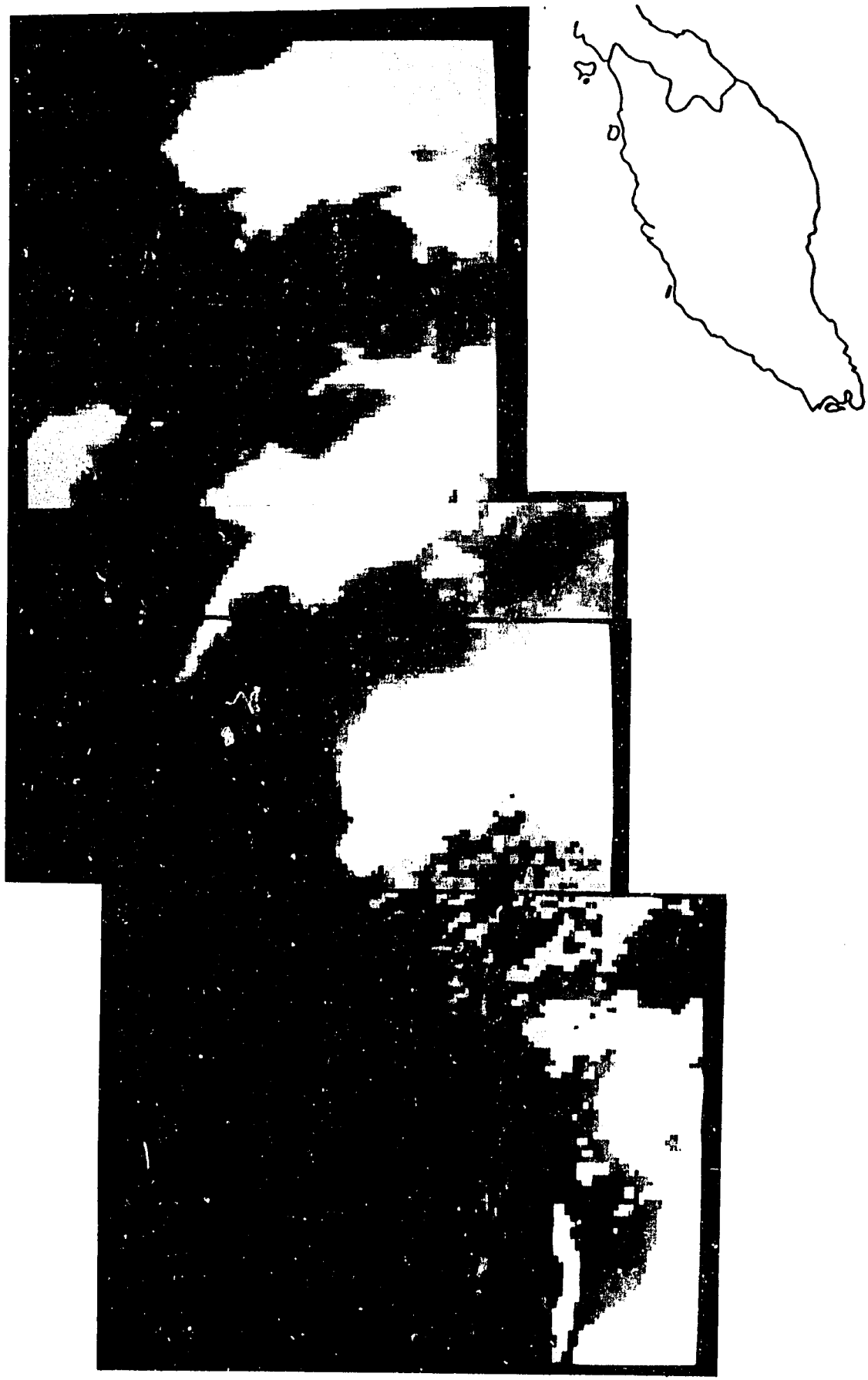
Table 1. Features that can be identified from the AVHRR images.

PENINSULAR MALAYSIA - CENTRAL WEST COAST

(May 20, 1984)

Image 1





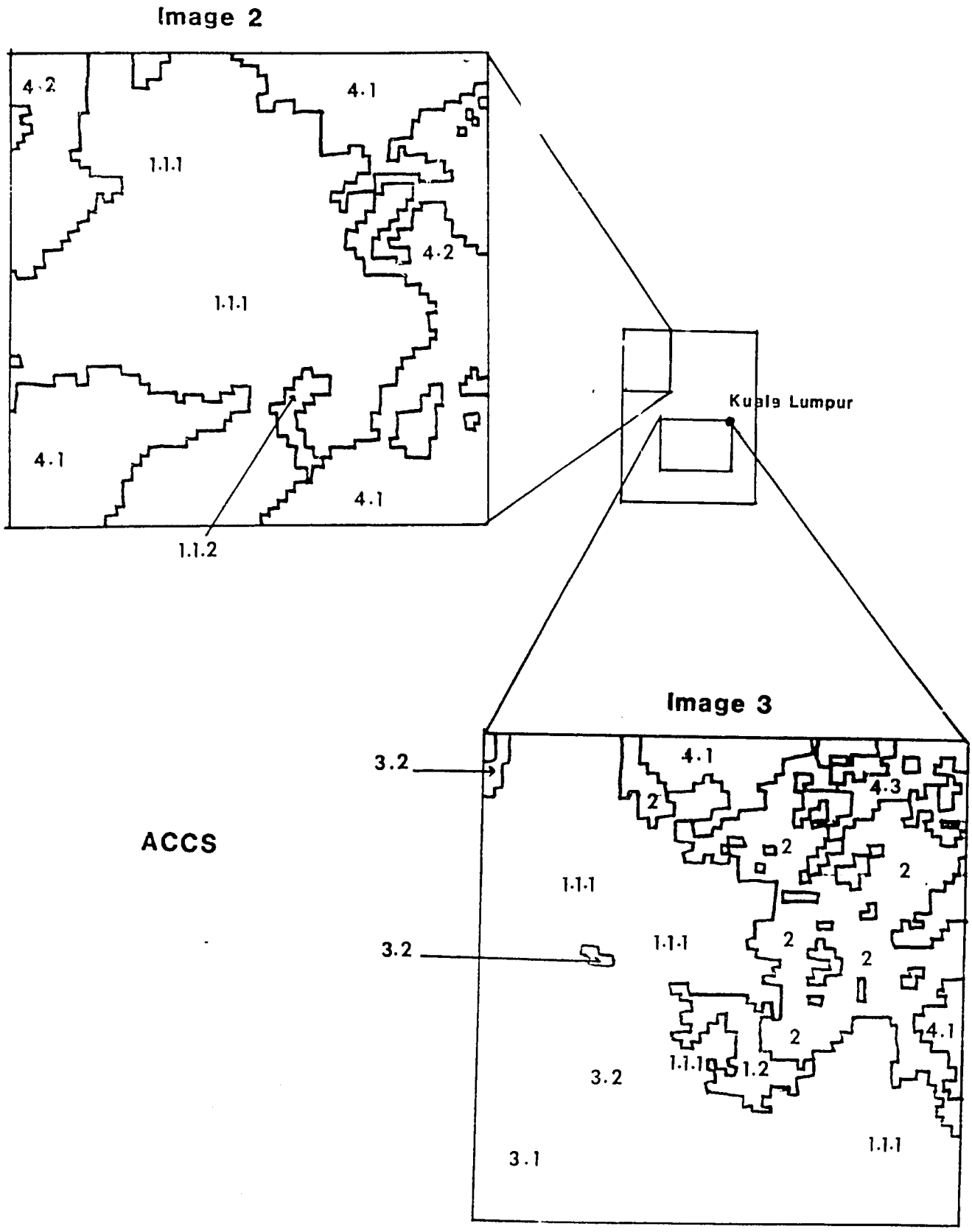


Image 2
4.2
4.1
1.1.1
4.2
1.1.1
4.1
4.1
1.1.2
Kuala Lumpur
Image 3
3.2
4.1
2
4.3
2
2
1.1.1
3.2
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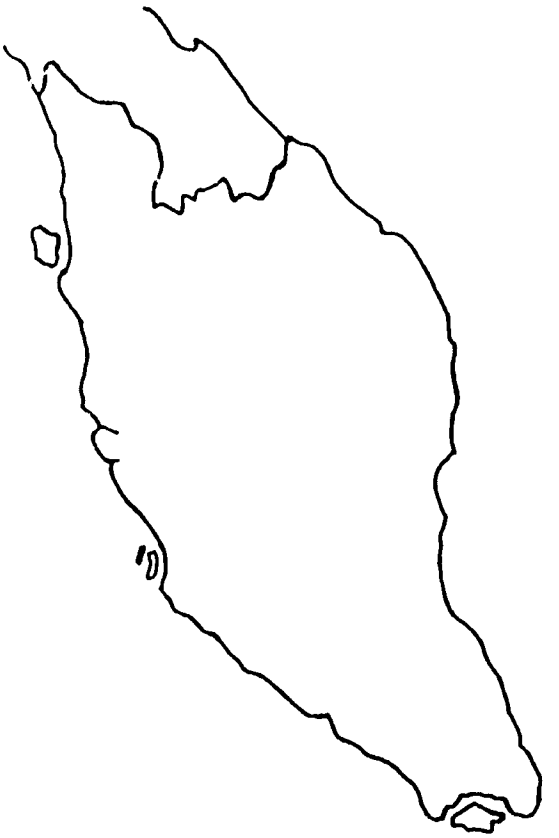
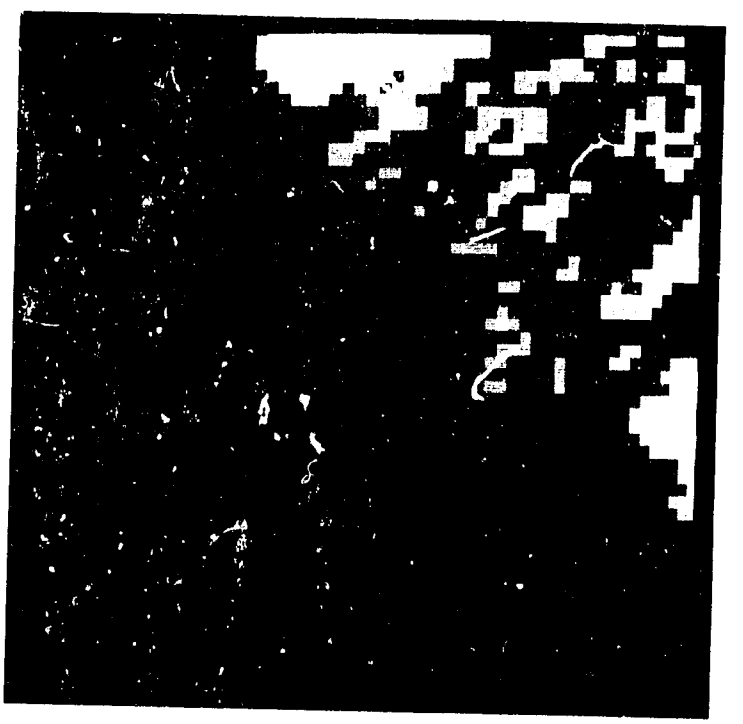
1.1.1
3.1

ACCS





TRAINING SET EXAMPLE 2

Training Set Example 2 consists of three pages of imagery labelled Image 4, 5, 6, 7 and 8 in the following discussion. The images were taken on June 17, 1984. Although it is heavily covered by clouds some of the major cropping areas in the northwest and central regions are quite clearly seen in image 4.

This second exercise concentrates on these two areas. Emphasis is given to paddy because it is a staple food crop. Information obtained from these paddy areas are useful for the Agro-Climatic Impact Assessment Programme in the country. A brief summary of this program is given in Appendix A.

KEDAH-PERLIS PLAIN: PADDY GROWING AREAS

This is a flat coastal plain of the main paddy growing areas of the country as shown in figure 5. The other important feature is the Temengor Dam, marked D.

Image 6 shows a closer look at the paddy area - several different colors are seen. These differences in color are probably due to different growing stages of the paddy plant. For example, the green color could be due to the early vegetative stages and the cyan color could be associated with the late vegetative stage and the reproductive stage, during which the field has a denser foliar coverage and higher biomass. Light brown color at the coastal areas, by comparison, could probably be associated with the transplanting period or uncultivated paddy field. Therefore, the difference in colors and the interpretation may require field verification.

SELANGOR PADDY GROWING AREAS

Image 7 covers another important paddy area. Apart from the paddy fields, tin mining areas of the Kinta river valley can also be identified.

Image 8 can be used to identify the paddy and peat areas. The brown color of the paddy field is probably associated with the transplanting stage. The cyan and green colors indicate a higher biomass of paddy plant at the later growth stages. If we refer back to image 2, a change in color of paddy areas is clearly seen. The brown area is no longer seen in image 8 since the paddy plants have passed the transplanting stage. The peat forests are considered to be important because it is served as a catchment area.

PENINSULAR MALAYSIA

(JUNE 17,1984)

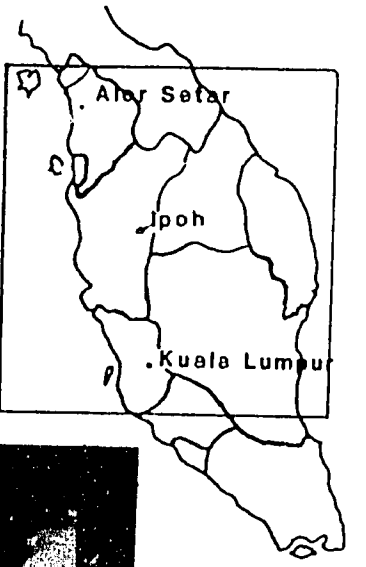
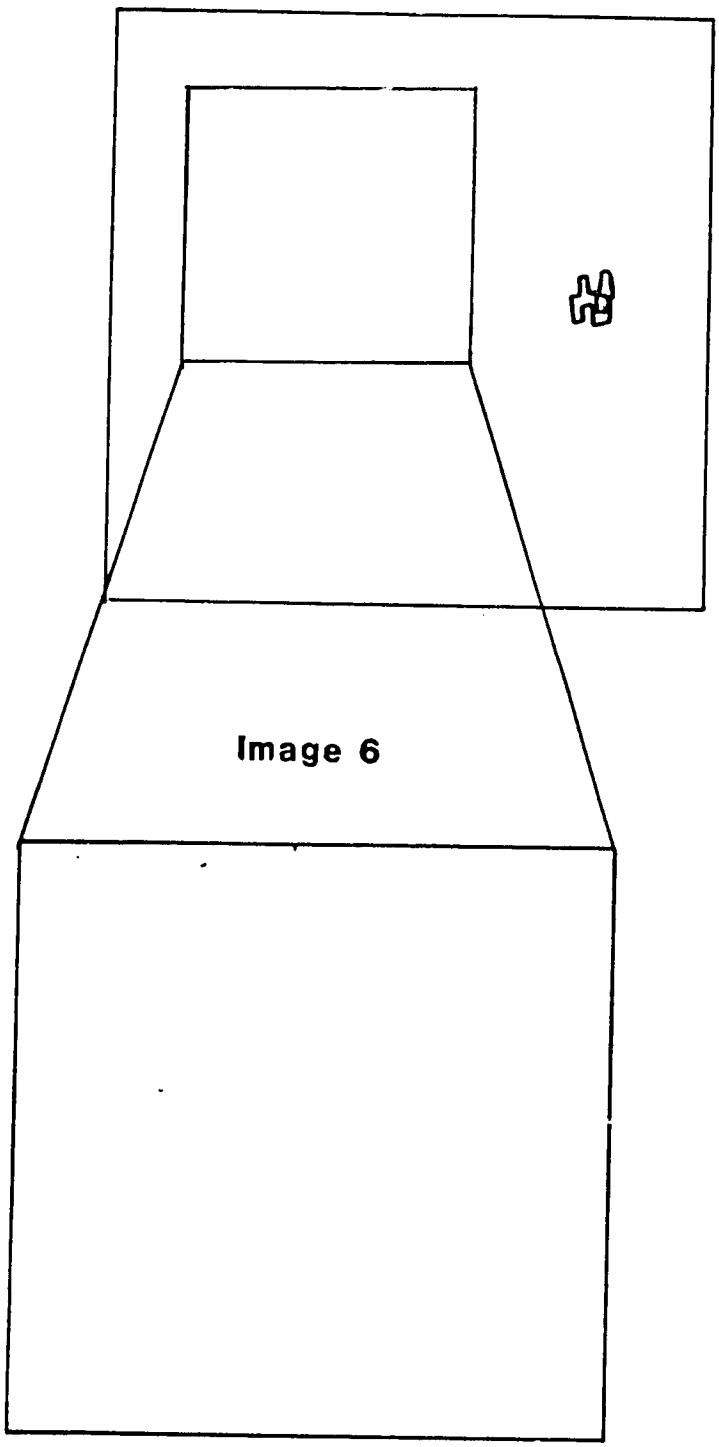


Image 4

Image 5



KEDAH-PERLIS PLAIN : PADDY GROWING AREAS

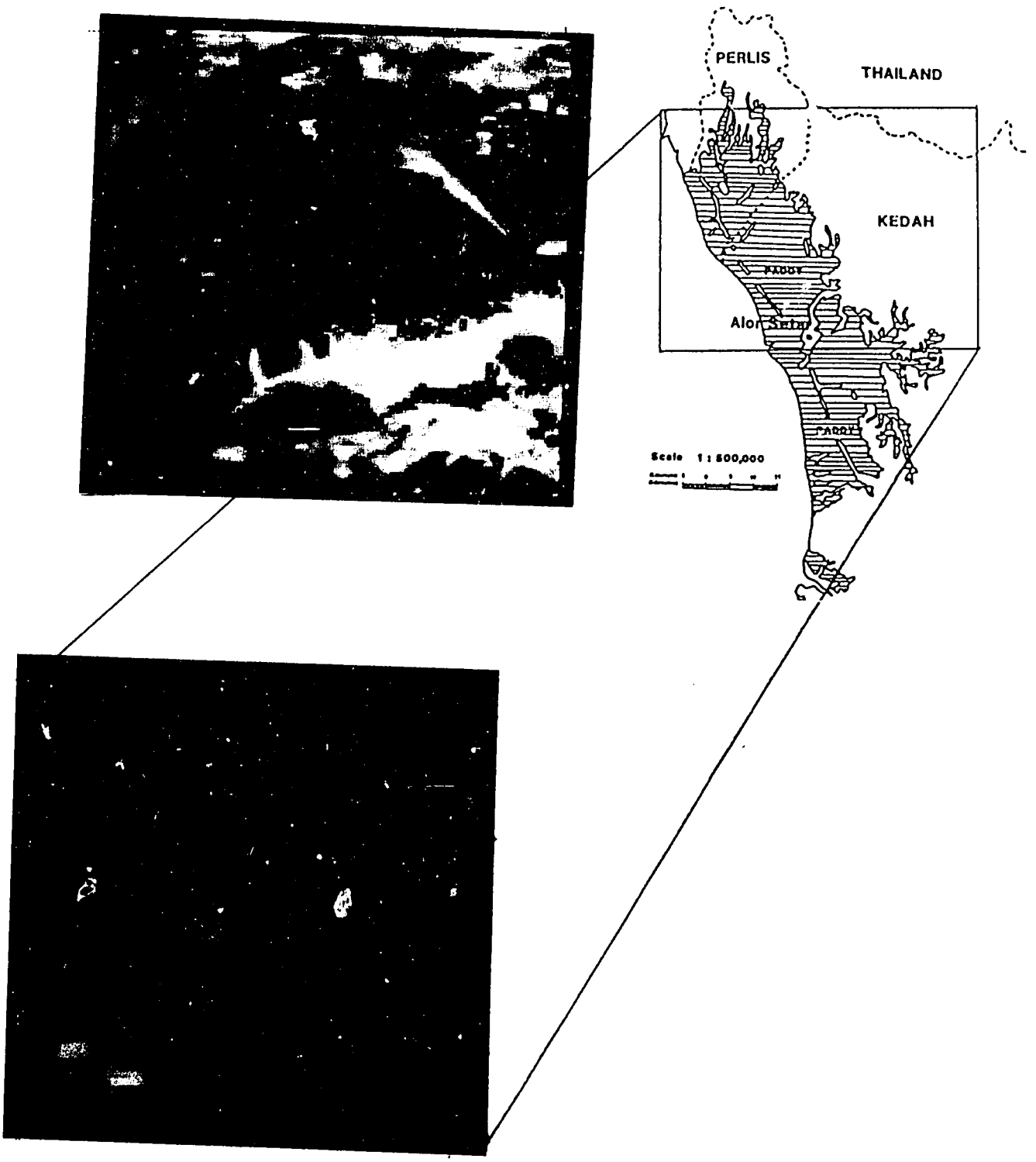
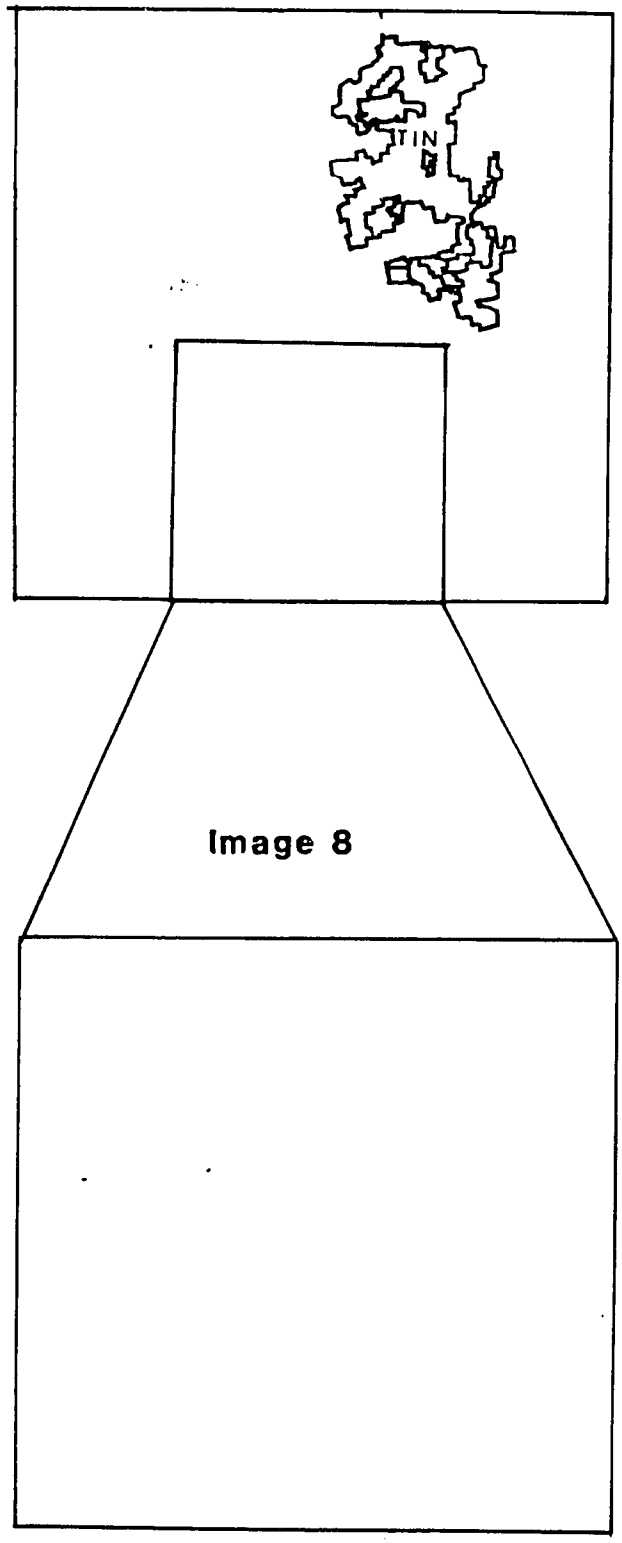
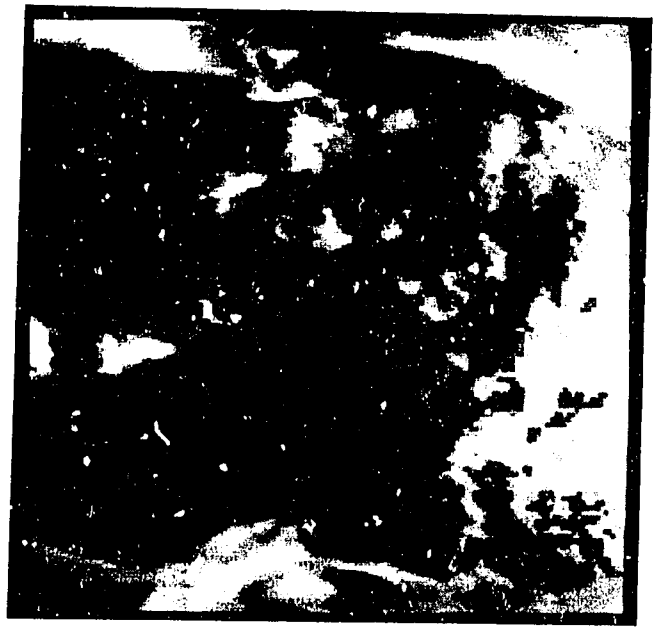
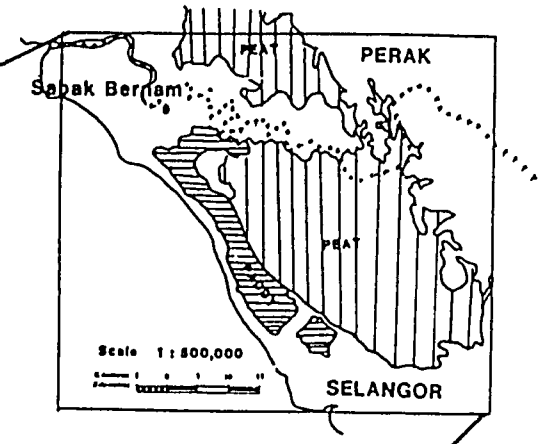


Image 7



SELANGOR : PADDY GROWING AREAS





7. CONCLUSIONS

This training course has enhanced our understanding of how the agroclimatic impact assessment process functions, including its purposes, principles and limitations. It has also provided us with knowledge of a new assessment tool (the combination of AVHRR channel 1 and channel 2 data) to complement our National Agroclimatic Impact Assessment Programme. This tool should not be used as a "stand alone" technique, but combined with other crop assessment techniques.

The AVHRR data are used in two forms in the assessment procedure, the time series of color enhanced images and the time series plots of satellite vegetation index. More information can be extracted from these color enhanced images if field verification is carried out. Images taken near to the satellite subpoint can also be used to compute approximately the acreage of a cropping area by counting the number of pixels and multiplying by 1.1 X 1.1 km^2.

One main disadvantage of using satellite data for crop assessment in the equatorial regions is that most of the time the sky is cloudy. To overcome this problem, a weekly compositing algorithm is applied to the daily data to aid in removing the clouds. Currently this technique is applied only to the PSG data and its resolution is rather coarse for the Malaysian region. There is a need to develop this technique further for the HRPT data to make the satellite assessment method more useful.

On the whole, the six-week training at the Models Branch of NOAA in Columbia, Missouri and in Washington, D.C. is excellent and has achieved its goal.

8. RECOMMENDATIONS FOR THE FUTURE

From this training course it was found that the satellite assessment method can be used to compliment the Agroclimatic Impact Assessment Programme in Malaysia.

Before this method can be put into operation, several requirements need to be available. These include the need to acquire:

(i) PC Microcomputer with 256K RAM and other necessary peripherals (Appendix D).

(ii) Software package for processing satellite data from the computer tapes to diskettes.

(iii) Software package for displaying multispectral enhanced color images using ACCS.

(iv) Software package for weekly compositing algorithm technique for HRPT data.

It is recommended that expert guidance be made available to solve any technical problems that may arise during the early stages of implementation.

Satellite assessment method works best when it is used along with other sources of information like ground truth data. To obtain maximum information from the multispectral enhanced color image, field verification is essential.

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GLOSSARY

ABSORPTANCE: A measure of the ability of a surface to absorb incident energy, often at specific wavelengths.

ABSORPTION: The process by which radiant energy is absorbed and converted into other forms of energy.

ACCS: Ambroziak Color Coordinate System. A method of display based on intensity, hue and saturation which is helpful for interpretation of an image.

ACCS-2b: A form of the ACCS which cycles the hues at twice the rate of that used in the ACCS. The 2b represents two sides of the color triangle between index values of zero and one, with blue on the diagonal or zero index value (45° angle of the color triangle).

ACCS-2r: Same as the ACCS-2b, except that the 2r represents two sides of the color triangle between index values of zero and one, with red on the diagonal or zero index value (45° angle of the color triangle).

ARBITRARY INDEX COLOR SYSTEM (AICS): A color system which uses a few colors to maximize perceptual resolution. This system does not contain all of the image information generally desired.

ASCENDING NODE (AN): The point at the equator at which the satellite in its orbital motion crosses from the southern to the northern hemisphere. Terrestrial Ascending Node (TAN) is given in degrees longitude. Celestrial Ascending Node (CAN) is given on right ascension hours, minutes, etc.

ATMOSPHERIC ATTENUATION: The reduction of radiation intensity due to absorption and/or scattering of energy by the atmosphere; usually wavelength dependent; may affect both solar radiation traveling to the earth and reflected/emitted radiation traveling to the sensor from the earth's surface.

ATMOSPHERIC WINDOWS: Those wavelength ranges where radiation can pass through the atmosphere with relatively little attenuation; in the optical portion of the spectrum, approximately 0.3 to 2.5, 3.0 to 4.0, 4.2 to 5.0, and 7.0 to 15.0 μm.

ATTITUDE (SATELLITE): The position of the axis of a satellite with respect to (a) its orbital plane, (b) the earth's surface, or (c) any fixed set of coordinates.

AVHRR: Advanced Very High Resolution Radiometer; part of the payload on board the NOAAn satellites.

AZIMUTH (α): A horizontal direction expressed in degrees measured clockwise from an adopted reference direction, usually true north.

BACKGROUND: The area on an image or the terrain that surrounds the area of interest or target.

BAND: A wavelength interval in the electromagnetic spectrum.

BLACKBODY: An ideal absorber and ideal radiator which absorbs all the radiant energy incident upon it and emits radiation at all wavelengths.

BRIGHTNESS: The attribute of visual perception in accordance with which an area appears to emit more or less light.

CCT: Computer Compatible Tape, the magnetic tape upon which the digital data for the satellite images are recorded, suitable for analysis on a general purpose computer.

CELL: An area on the ground from which EMR is emitted or reflected.

CLASSIFICATION: The process of assigning individual pixels of a multispectral image to categories, generally on the basis of spectral-reflectance characteristics.

CLUSTERING: The analysis of a set of measurement vectors to detect their inherent tendency to form clusters in multidimensional measurement space.

COLOR: That property of an object which is dependent on the wavelength of light it reflects, or emits.

COLOR COMPOSITE IMAGE: A color image prepared by projecting individual black and white multispectral images in color.

COVERAGE: The ground area represented on aerial photographs, photomosaics, or maps.

DATA: Numerical or quantitative notations.

DATA-ACQUISITION SYSTEM: The collection of devices and media which measures physical variables and records them prior to input to the data-processing system.

DATA COMPRESSION: Any technique that condenses the available data so as to make data storage or transmission more efficient with minimal loss of information.

DECLINATION (δ): The angular distance of an object north (+) or south (-) from the celestial equator measured along the hour circle passing through the object.

DENSITY: In an optical image a point-by-point measure of the degree of blackness; often used in a more general sense to refer to relative intensities in remote sensing data.

DESCENDING NODE (DN): The southbound equator crossing of the satellite; given in degrees longitude, date, and time for any given orbit or pass.

DISTORTION: On an image this refers to changes in shape and position of objects with respect to their true shape and position.

ELECTROMAGNETIC RADIATION (EMR): Energy propagated in the form of an advancing interaction between electric and magnetic fields (EMR).

ELECTROMAGNETIC SPECTRUM: The ordered array of known electromagnetic radiations.

EMISSION: The process by which a body emits electromagnetic radiation, usually as a consequence of its kinetic temperatures.

FALSE COLOR IR SYSTEM: A color coordinate system in which the colors are shifted towards the longer wavelengths. In this system, blue is generally dropped, green is assigned a blue color, red becomes green, and near IR is represented as red.

FAR INFRARED: A term for longer wavelengths of the infrared region, from 7.0 μm to 15.0 μm.

FEATURE: In pattern recognition, one of the measurements of a pattern or a mathematical transformation of such measurements; in remote sensing, often the reflectance measurement in one channel of the sensor. The number of features associated with a pattern defines its dimensionality.

FORMAT: Size and scale of an image.

GAC: Global Area Coverage, an image format of the AVHRR data of the NOAA satellite; each pixel represents an area of about 16 km^2.

GEOMETRIC TRANSFORMATIONS: Adjustments made in the image data to change its geometric character, usually to improve its geometric consistency or cartographic utility.

GMI: Gray-McCrary index, a vegetation index constructed from the NOAA-AVHRR data, calculated as follows: $GMI = Ch_2 - Ch_1 + 100$.

GROUND RECEIVING STATION: A facility that records image data transmitted by a satellite.

HUE: The attribute of a color that differentiates it from gray of the same brillance and allows it to be classed as blue, green, red or intermediate shades of these colors.

IMAGE: The representation of a scene as recorded by a remote sensing system. Although image is a general term it is commonly restricted to representations acquired by non-photographic methods.

IMAGERY: The product of image forming instruments (analogous to photography).

INFRARED (IR): Pertaining to energy in the 0.7 - 100 μm wavelength region of the electromagnetic spectrum. For remote sensing, the infrared wavelengths are often subdivided into near infrared (0.7 - 1.3 μm), middle infrared (1.3 - 3.0 μm) and far infrared (7.0 - 15.0 μm). Far infrared is sometimes referred to as thermal or emissive infrared.

INSTANTANEOUS FIELD OF VIEW: A term specifically denoting the narrow field of view designed into scanning radiometer systems.

INTENSITY: Apparent brightness of light.

IRRADIANCE: The measure of radiant flux per unit area falling on the surface of a body.

LAC: Local Area Coverage, an image format of the AVHRR data of the NOAA satellite. (One pixel represents an area of about 1.2 km^2.)

LAI: Leaf Area Index; can be defined by the averaged leaf area per ground area occupied by a crop.

LOOK ANGLE: Direction of the look or direction in which the sensor is pointing when transmitting or receiving from a particular cell.

MICROMETER: (μm) a unit of length equal to 10^{-6} of a meter or 10^{-3} millimeter.

MIXED PIXEL: A pixel containing more than one target.

MSS: Multispectral Scanner.

MULTISPECTRAL SCANNER: A line-scanning sensor which uses an oscillating or rotating mirror, a wavelength-selective dispersive mechanism, and an array of detectors to measure simultaneously the energy available in several wavelength bands, often in several spectral regions. The movement of the platform usually provides for the along-track progression of the scanner.

NADIR: The point on the ground vertically beneath the perspective center of a remote sensing system.

NEAR INFRARED: Part of the electromagnetic spectrum that includes wavelengths from 0.7 to 1.3 micrometers.

NESDIS: National Environmental Satellite, Data, and Information Service.

NOAA: National Oceanic and Admospheric Administration.

NODE: The points at the equator at which the satellite in its orbital motion crosses the equator. The line connecting the ascending and the descending nodes is called the line of nodes.

NOISE: Random or repetitive events that obscure or interfere with the desired information.

ORBIT: The path of a satellite around a body under the influence of gravity.

PATTERN RECOGNITION: The automated process through which unidentified patterns can be classified into a limited number of discrete classes through comparison with other class-defining patterns or characteristics.

PAYLOAD: Equipment a satellite carries necessary for the operation of the vehicle during its flight.

PERCEPTUAL RESOLUTION: The perceived resolution of a color coordinate system by the mind.

PIXEL: Picture Element is the area on the ground represent represented by each digital value.

PSG: Polar Stereographic projection; a cartograhic projection of the sphere in which the point of sight is at the center and the plane of projection passes through one of the polar circles.

RADIANCE: Radiant flux (watts)

RADIATION: The propagation of energy in the form of electromagnetic waves.

RADIOMETRIC CORRECTION: All those operations intended to correct known faults in the image due to sun angle differences, differences in instrument calibration, and differences in atmospheric conditions.

REAL TIME: To make images available for interpretation simultaneously with their acquisition.

REFLECTANCE: The ratio of radiant energy reflected by a body to that incident upon it.

REGISTRATION: The process of geometrically aligning two or more sets of image data such that resolution cells for a single ground area can be digitally or visually superimposed. Data being registered may be of the same type, from very different kinds of sensors, or collected at different times.

REMOTE SENSING: The collection of information or electromagnetic radiation from an object without being in physical contact with the object.

RESOLUTION: The ability of an entire remote sensor system to render a sharply defined image (lines per mm).

SATELLITE: An object in orbit around a celestial body.

SATURATION: The degree to which hue is undiluted by white light.

SCALE: Ratio of the distance on an image to the equivalent distance on the ground.

SCAN LINE: The narrow strip on the ground that sweeps across the flight direction of the detector in a scanner system.

SENSOR: Any device which gathers energy (EMR) or other data and presents it in a form suitable for obtaining information about the environment.

SPECTRAL BAND: An interval in the EMR spectrum defined by two wavelengths, frequencies or wave numbers.

SPECTRAL RESPONSE: The response of a material as a function of wavelength to incident electromagnetic energy, particularly in terms of the measurable energy reflected from and emitted by the material.

SPECTRAL SIGNATURE: The spectral characterization of an object or class of objects on the earth's surface. Often used in a way which naively over-simplifies the complexity of the spectral representation problem in a natural scene.

SPECTROMETER: An optical instrument used to measure the apparent electromagnetic radiation emanating from a target in one or more fixed wavelength bands or sequentially through a range of wavelengths.

SUN-SYNCHRONOUS ORBIT: Nominally a retrograde, quasi-polar orbit such that the satellite crosses the equator on the ascending node always at the same local (solar) time.

SWATH WIDTH: The overall plane angle or linear ground distance covered by a multispectral scanner in the across-track direction (transverse to the direction of travel of the sensor platform).

SYNCHRONOUS SATELLITE: A satellite in a west-to-east orbit of the earth at an altitude of 22,300 statute miles. At this altitude it circles the axis of the earth once in 24 hours. Thus its speed in orbit is synchronous with the earth's rotation.

TARGET: The portion of the earth's surface which produces by reflection or emission the radiation measured by the remote sensing system.

TERRESTRIAL: The term used to designate a line or a point on the earth's surface.

TRACK: The actual path of an aircraft above the surface of the earth.

VEGETATION INDEX: Mathematical combination of the different bands that have been found to be sensitive indicators of the presence of green vegetation.

VISIBLE RADIATION: Energy at the wavelength from 0.4 to 0.7 μm, that is detectable by the eye.

ZENITH: The point in the celestial sphere that is exactly overhead as opposed to Nadir.

APPENDIX A

AGRO-CLIMATIC IMPACT ASSESSMENT PROGRAMME OF MALAYSIA.*
(A Brief Summary)

prepared by

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Kuala Lumpur
Malaysia

A. Scope and Objectives

Agro-climatic Impact Assessment Programme (AGROCIA) is a Service oriented programme whereby all factors relating to crop growth are regularly monitored and assessed for the purposes of crop performance and production forecasting.

B. Benefits of Programme

(a) Information provides decision makers ample lead time to develop plans for storage, transporation, etc.

(b) Information is useful for making decisions on import or export of commodities.

(c) Information permits efficient utilization of available water resources.

C. Institutional Arrangement

(a) National Implementation Committee - a committee responsible for policies and approval of bulletins (Table 1).

(b) Inter Department Technical Committee - a committee responsible for operation of programme. Composition and duties are listed in Table 2.

* Presented at the Integrated Agriculture Development Project components meeting on AGROCIA, Seberang Perai, Penang, Mar. 29, 1985.

D. Operational Procedure

The flow diagram is shown in Table 3.

(a) Identification of all possible factors affecting production.

(b) Monitoring of dynamic factors at regular time intervals.

(c) Evaluation of common agro-climatic indices.

For Paddy Plant:

Generalized Monsoon Index (GMI) where

$$GMI = 0.125\ P_1 + 0.125\ P_2 + 0.5\ P_3 + 0.25\ P_4$$

Yield Moisture Index (YMI) where

$$YMI = 0.95\ P_1 + 1.05\ P_2 + 1.05\ P_3 + 0.85\ P_4$$

Crop Water Requirements (WR) where

$$WR = Kc.PET$$

(d) Assessment of all factors affecting production, including assessment of ground conditions.

(e) Production of Bulletin.

E. Output of Programme

Monthly and special bulletins are issued by AGROCIA. The information highlighted is

(a) Crop pests and climatic conditions for the month.

(b) Other information such as expected date of harvest, expected production, and regions of high crop activity.

A copy of the bulletin for the month of November for the MADA region is attached.

F. Target Groups or End Users of AGROCIA

Mainly senior officials involved in the process of decision making at the ministerial, departmental and ground levels.

G. Other Activities

Application of remote sensing as a tool for the purpose of

(a) estimating crop acreages according to growth stages.

(b) detecting areas affected by pests and diseases.

(c) estimating acreage damaged by floods.

TABLE 1. COMPOSITION OF NATIONAL IMPLEMENTATION COMMITTEE

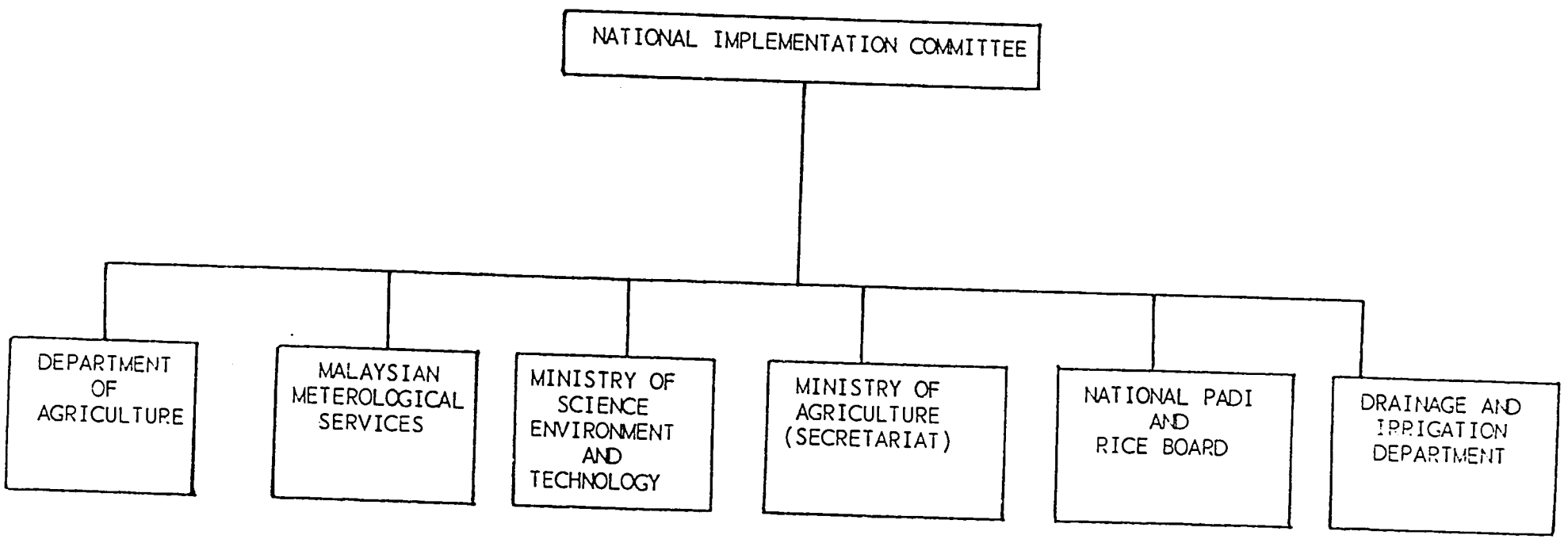


TABLE 2. : COMPOSITION AND EXPECTED DUTIES OF THE INTER-DEPARTMENTAL TECHNICAL COMMITTEE

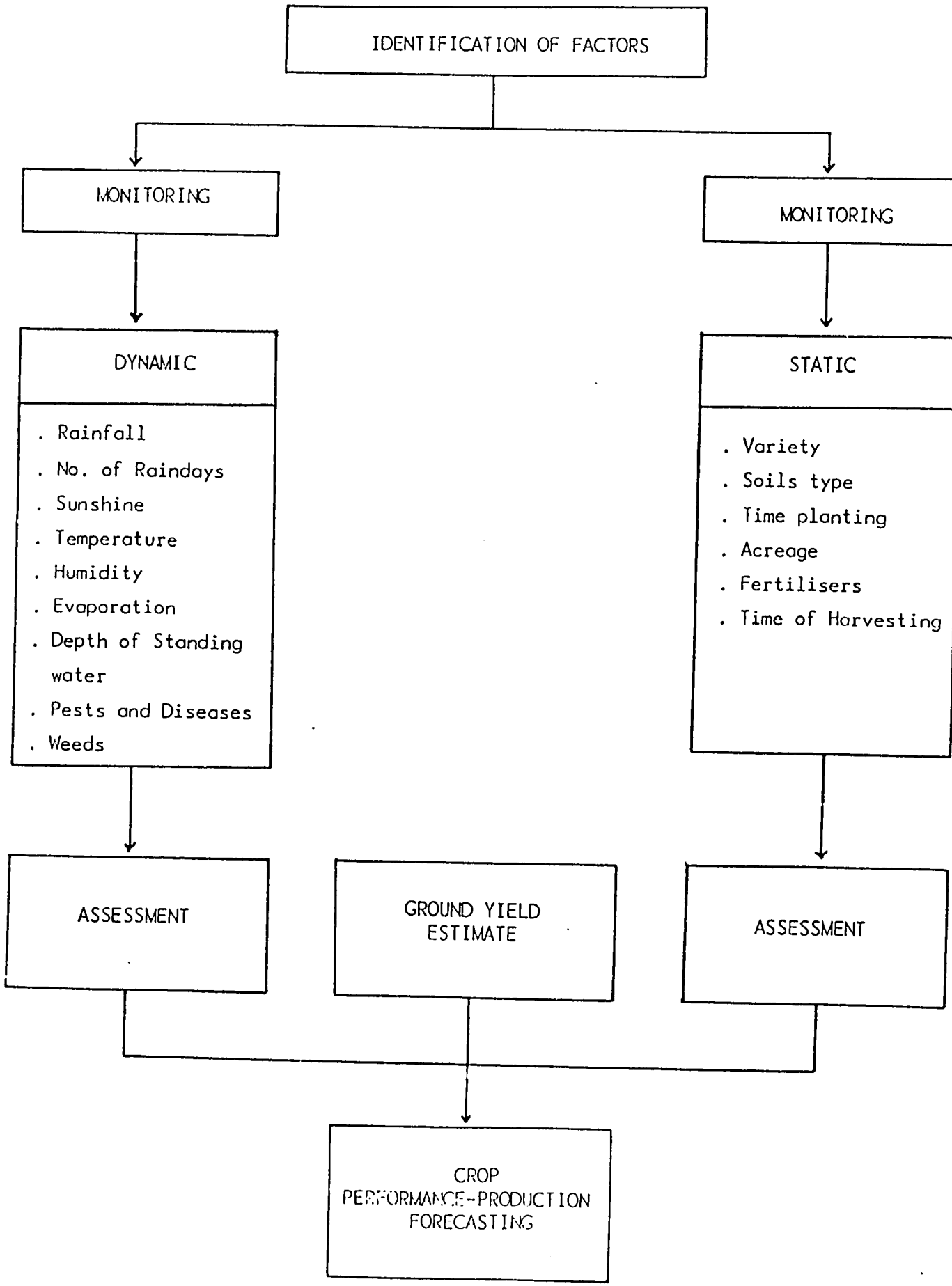
INTER-DEPARTMENTAL TECHNICAL COMMITTEE
ON
AGRO-CLIMATIC IMPACT ASSESSMENT

Soil Scientist	Agrometerologist	Hydrologist	Agronomist	Entomologist	Agriculture Economist
DOA	MMS	DID	DOA	DOA	MOA
Collect, analyse and monitor soil moisture conditions of planted areas. Together with other members, undertake studies relating all factors with yield. Prepare and submit monthly summary.	Collect, verify and analyse all climato logical data recorded at MMS station. Prepare and submit monthly summary. Initiate studies relating climate to crop yield.	Collect, verify and analyse all climatological data of DID station. Monitor and estimate acreage affected by floods. Prepare and submit monthly summary. Assess and monitor water reserves available for irrigation.	Collect, analyse and monitor management and physical inputs. Together with other members, undertake monitoring of moisture in relation to crop water requirements. Prepare and submit monthly summary.	Identify, monitor and estimate areas affected by pest and disease. Prepare and submit monthly summary. Undertake studies relating climate to incidence of diseases.	Collect, verify and monitor acreages of crop planted. Collect and analyse useful economic indicators. Prepare and submit monthly summary.

TABLE 3.

AGROCIA

MECHANISMS OF OPERATION



AGRO-CLIMATIC IMPACT ASSESSMENT REPORT NO.5
(NOVEMBER, 1984)
North-West Peninsular Malaysia (MADA, Kedah and Perlis)

Impact

Much below normal rainfall insufficient to meet the water requirements of padi were recorded during the month for the region. Unless steps are taken to irrigate the crop, yield of padi is likely to be affected for this season. This is based on the following reasons.

a) the amount of rain which fell since the 20th of this month is reportedly low and insufficient to meet the water requirements of the crop.
b) most of the padi planted in the region are either at the vegetative or early reproductive stage.
c) the water requirements of the crop are not likely to be met in the coming months of December, January and February since those are normally the driest months of the year.

However, we understand that irrigation has been carried out in this period. Thus, with the abundant sunshine during this relatively drier period as well as irrigation water meeting the sunshine requirements of the crops the padi plants are still expected to perform well despite the drier condition.

During the month, an additional 42,000 hectares were planted of which 35,000 hectares were in MADA region, and 7,000 hectares outside MADA area. The acreage of padi affected by pest/

..2/-

diseases in MADA has increased to 1860 hectares while no significant change in acreage affected by pest/diseases was reported outside MADA.

Weather Analysis

The mean total rainfall of the month was slightly above 100 mm or about 45% of normal. Most of the rain came in the first half of the month. In fact about one-third of the rainfall stations used in this analysis reported no rainfall at all for the last 10 days of the month. These rainfalls were insufficient to meet the water requirement of padi.

The agroclimatic indexes calculated for the months of October and November were also below normal, on the average ranging from 60 to 70% of the normal. Their percentile rank had a mean value of 15 which implied that this relatively drier condition has a probability of occurance of once in 7 to 8 years.

..3/-

TABLE I: PADI ACREAGE IN KEDAH AND PERLIS - MAIN SEASON (NOVEMBER)

Area	Under Preparation (ha)	Planted (ha)	Flowering (ha)	Matured (ha)	Harvested (ha)	Pest & Disease[1] (ha)
MADA	95,637	94,990	97	0	0	1,863
OFF MADA						
i) Kedah[3]	29,077	27,693	N.A	N.A	N.A	5,592[2]
ii) Perlis	7,216	7,216	N.A	N.A	200	0

(1) Acreage affected
(2) 5353 ha. was affected by pest (scrangga) whereby 41 ha. were destroyed.
(3) Not including the districts of Langkawi, Kulim, Baling, dan Bandar Baru.

N.A.- Not available.

TABLE 2: PRECIPITATION

AREA	RAINFALL (mm)		PERCENTAGE NORMAL	
	Mean	Range	Mean	Range
MADA (20 stations)	105	44 - 176	48%	22 - 84%
OFF MADA				
i) Kedah (8 stations)	118	54 - 173	45%	24 - 61%
ii) Perlis (6 stations)	131	63 - 174	42%	28 - 85%

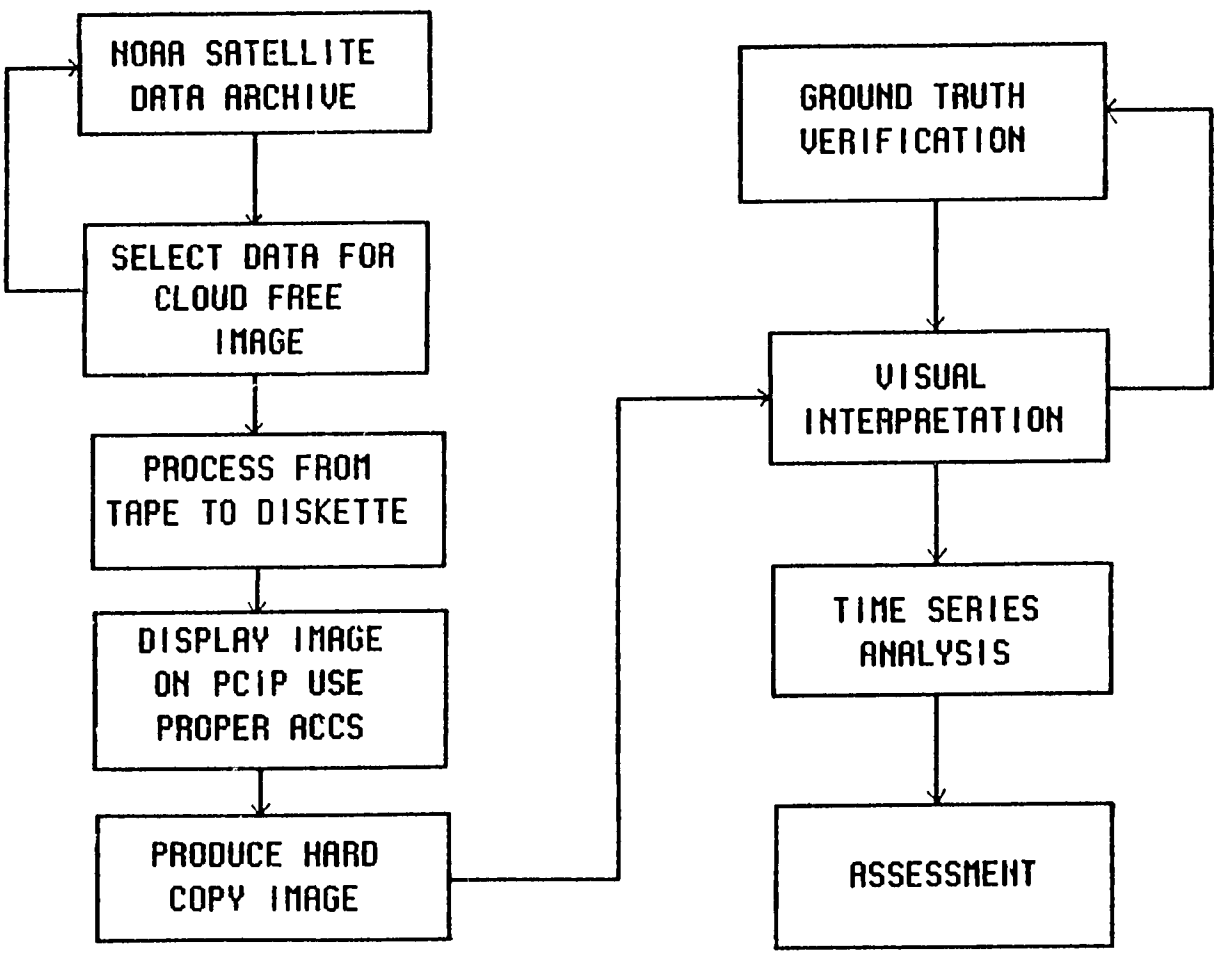
TABLE 3: YIELD MOISTURE INDEX (YMI)

Area	Mean YMI	Range	% Normal	Percentile
MADA (20 stations)	289	222 - 423	60%	13
OFF MADA				
i) Kedah (8 stations)	344	213 - 458	60%	14
ii) Perlis (6 stations)	321	207 - 349	69%	16

TABLE 4: GENERALISED MONSOON INDEX (GMI)

Area	Mean GMI	Range	% Normal	Percentile
MADA (20 stations)	154	118 - 234	62%	15
OFF MADA				
i) Kedah (8 stations)	187	153 - 251	62%	16
ii) Perlis (6 stations)	168	140 - 182	71%	17

FLOWCHART OF NOAA-SATELLITE DATA FOR CROP ASSESSMENT PROGRAMME.



APPENDIX C

Operation of Personal Computer Image Processor (PCIP package)

This section describes the use of software for image analysis on a personal computer. Prior to the development of this software, image processing could be done only on large, very expensive equipment. In contrast, this software is designed to run on a personal computer, costing a mere fraction of this total. Furthermore, extensive training is required in order to gain proficiency on the large image processor. The software programs contain simple commands and can be learned in a very short time. This allows the trainee to focus his efforts on mastering imagery analysis rather than computer procedures. A second manual is being prepared by AISC for training in basic color science and satellite imagery interpretation.

This section documents the software program and describes its use. Also included is a description of how the satellite data is processed and formatted for use on the personal computer image processor. This represents the first version of the software. As users gain experience, requests for changes are anticipated. Hence, the following documentation should be considered preliminary. Suggestions for improvements are encouraged.

7.1. Operational Procedure

This is a preliminary version of the personal computer image processor program. This version allows the user to display an image, zoom and pan. Once the image is read you cannot change the colors. You can exit the zoom and pan mode and read in another color table or create a new color table. Creating new color tables that can be stored on file is done through the headgen program. You can make a temporary table by exiting the zoom and pan mode and following the prompts. Setting up an image is easily

done by following the steps below. The example below indicates what the user actually types by using underlined print. Once the image is selected from the diskette, all the user has to do is select the size and location of the color legend. The program then is in the zoom and pan mode for analyzing the image.

1. Turn on computer and peripherals.
2. DOS operating disk in Unit A
3. Type Init (with graphics diskette in Unit A)
4. Put program Disk in Unit A (pcip)
5. Data Disk in Unit B
6. Following the prompt sign A > Type the following:

   pcip b: filename

   The filename indicates the date of the image; for example: H4339.30C. The pcip means personal computer image processor program. This step loads the program, computes and loads the color table, and loads the image into memory with image displayed.

7. The user is prompted to position the color triangle and must designate x & y coordinates from 0 to 512 (typically 0,0 works well as the color triangle is put in the upper left corner).

8. Select size of legend (1-4)---3 is very good for demonstrating the colors, but may cover part of the image, 1 is more practical when doing analysis.

9. Zoom and pan mode is now in place. Use page up and down for zoom, use arrows to pan - the image moves in the direction of the arrow.

10. To exit from zoom, hit the "escape key" (esc) or hit "control e" (Ctrl E).

11. If you depress these keys, the program asks if you want new color tables.

12. If yes, then type new header (e.g., b: THAI01.LUT). The image will then use this color table to display the image. Color tables are created in the next section.

7.2. Look Up Table (LUT)

Images can be made brighter or darker and certain object (clouds) highlighted by altering the look up table (LUT). This is accomplished by using the "HEADGEN" program which creates a LUT that is stored and can be

retrieved from disk file. This program allows the user to enter values for intensity, hue and saturation. There are 16 intensity levels, 18 hues, and 12 saturations. These values determine the color and brightness of the pixels in the image. In general, the changes in brightness of vegetation are made by adjusting intensity and changes in clouds are made by changing the saturation table. By altering the hue table one is in effect changing the vegetation index.

To create a LUT, you type:

b: headgen THAI01.LUT

where b: is the disk drive's name.

HEADGEN is the program.

THAI01.HED is the name of the header or LUT. Hence, if you were to retrieve this LUT, it would be named THAI01.LUT.

7.2.1. Intensity Table

Once the file is named, the program prompts the user to enter number of intensity. The screen would show "intensity 0 = " and the user might enter 0. The user will then enter values for itab 1 through itab 15 (16 values total). The standard intensity table comprises 16 values ranging from 0 (zero intensity) to 255 (maximum brightness) at equal intervals of 17. The values are as follows:

itab [0] = 0
itab [1] = 17
itab [2] = 21*
itab [3] = 51
itab [4] = 68
itab [5] = 85
itab [6] = 102
itab [7] = 119
itab [8] = 136
itab [9] = 153
itab [10] = 170
itab [11] = 187
itab [12] = 204

itab [13] = 221
itab [14] = 238
itab [15] = 255

* 21 is used instead of 34.

These values range from 0 to 255 and produce a bright image. If one were to use multiples of ten from 0 to 150, the image would be considerably darker.

Hue Table

The hue table is created in a similar manner, but with values representing colors. The numbers are based on the color wheel with Blue = 0 or 252; Red = 84; and Green = 148. The remaining colors are combinations of these primary ones. The standard color table is as follows:

htab [0] = 42
htab [1] = 84
htab [2] = 100
htab [3] = 105
htab [4] = 109
htab [5] = 113
htab [6] = 116
htab [7] = 120
htab [8] = 126
htab [9] = 134
htab [10] = 152
htab [11] = 192
htab [12] = 212
htab [13] = 221
htab [14] = 226
htab [15] = 233
htab [16] = 242
htab [17] = 252

Saturation Table

The saturation table is used to manipulate cloud images. By lowering the saturation one sees more definition and the cloud becomes more 3-dimensional. However, one may not like to have grey clouds and

would prefer them to remain bright. An example of the latter case would be the following:

```
stab [0]  = 0
stab [1]  = 15
stab [2]  = 30
stab [3]  = 45
stab [4]  = 60
stab [5]  = 75
stab [6]  = 90
stab [7]  = 105
stab [8]  = 120
stab [9]  = 135
stab [10] = 150
stab [11] = 255
```

Finally, the program requests information about auxiliary colors. This will be used in the future, but the present version automatically adds black (zero intensity, zero hue and zero saturation) and you enter 0.

The program also asks the user to choose the number of records per file. An answer of 1 will permit the program to exit to DOS. In the future, the program will allow the user to add text annotation to the image.

Figure 21 is a block diagram showing how NOAA satellite data have been processed. The flow begins from the archive tape. Three of five available channels are used as input to the VAX 750 computer. These data are converted to vegetation index values, and stored on disk or made into floppy disks for subsequent analysis.

Satellite Data Processing and Storage

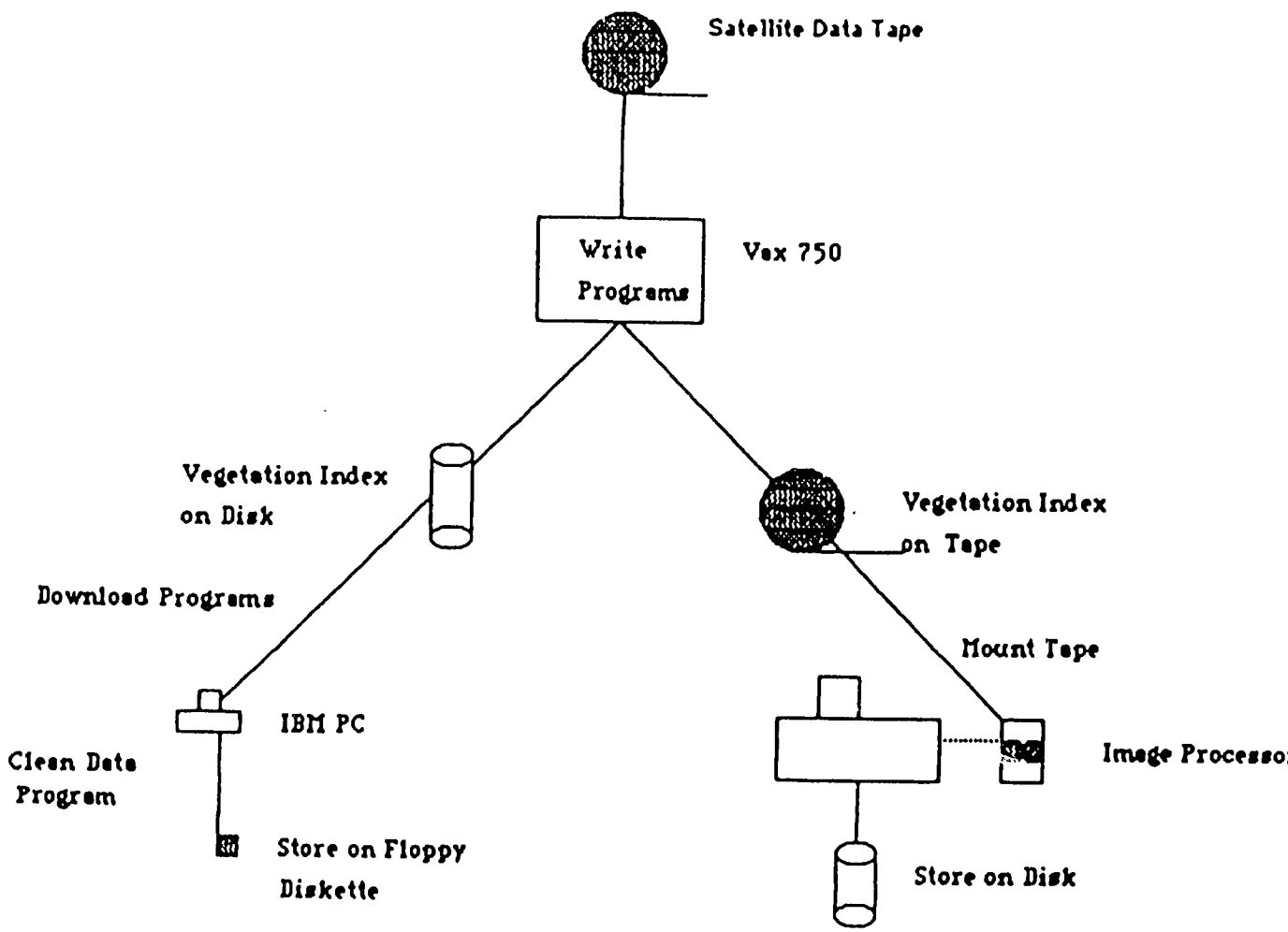


Figure 21

APPENDIX D

EQUIPMENT AND COST

Satellite Agroclimatic Assessment

Models Branch, Columbia, MO U.S.A.

IBM PC XT Micro Computer with 256K RAM	$3,000.00
1 360K Floppy Disk Drive	
1 10M Hard Disk	

OR

IBM PC Micro Computer with 256K RAM	$2,000.00
2 360K Floppy Disk Drive	
Color Graphics Board	$250.00
Monochrome Monitor	$200.00
Number Nine Graphics Board	$2,000.00
Hitachi High Res. RGB Monitor HM-2719	$3,000.00
Total cost with/XT	$8,450.00
Total cost with/PC	$7,450.00