STUDY ON STABILITY OF REFLECTANCE CHARACTERISTICS OF NATURAL FEATURES FOR CALIBRATING REMOTE SENSING DATA

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STUDY ON STABILITY OF REFLECTANCE CHARACTERISTICS OF NATURAL FEATURES FOR CALIBRATING REMOTE SENSING DATA

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A thesis submitted in partial fulfillment of the
requirement for the award of the degree of
Master of Science (Remote Sensing)

Faculty of Geoinformation and Real Estate
Universiti Teknologi Malaysia

APRIL 2014

This work is dedicated with love and joy to
Mom, Dad, Brother, Sister, Husband,
for their supporting hands and loving care,
thank you for everything.

ACKNOWLEDGEMENT

There has been a lot of challenging, always an inspiring and sometimes exciting but of course often new and interesting experience from the commencement until the completion of this thesis. This has been made possible by many people who have supported me in many ways.

I would like to express my appreciation to Prof. Dr Ibrahim Bin Busu for his everlasting enthusiasm, encouragement, precious advice and great concern in guiding for completing this thesis. I am deeply indebted to him for his time, endeavour and compassion.

Last but not least I would like to show gratitude to my lovely and supportive family, thank you for always gives the best for me. Additional thanks are extended to Mr Nizam for his assistance and all my friends especially my close friends Nurul Nadiah and Tam Tze Huey for their help and support during my postgraduate studies.

ABSTRACT

The development of satellite technology in Malaysia is to ensure the availability of satellite imaging for the requirement of local remote sensing user. Apparently, low-quality images were produced from local remote sensing satellite. The vicarious calibration technique can be adopted to provide post-calibration opportunity to overcome this problem. However, this approach has constraints in defining well establishing target bodies. Currently, reflectance based calibration approach had been used in the measurement but using only several test site as a calibration target. Malaysia with its tropical condition should be capable to provide natural bodies that stable enough to serve as calibration target. The main purpose of this study was to develop a spectral library for selected spatial features. The spectral library will serve as a reference for the calibration of the image data generated by the camera. Visible and near infrared (NIR) bands from Landsat 7 and SPOT XS images were used in this study to obtain reflectance value. These reflectance values were collected on the selected targets that are water bodies, dark dense vegetation, man-made features and cloud body. Reflectance curve of each features were compared with ASTER spectral library as reference. From the comparison it shows that reflectance curve from Landsat 7 and SPOT XS give almost similar reflectance curve with reference spectral library. The range of reflectance value for water features is from 0.018 to 0.028, vegetation features range from 0.01 to 0.5 and man-made features range from 0.05 to 0.4. Cloud features give range of reflectance values from 0.2 to 1. Statistical distribution for spectral reflectance was determined to calculate the mean, variance and standard deviation. These values were used to determine the minimum and maximum values of spectral reflectance for each feature. Graphs were plotted to show the interval of each features based on bands. From these graphs, there are maintain range of interval level which indicate that the measured reflectance is reliable enough for information extraction of the spectral library.

ABSTRAK

Teknologi satelit di Malaysia berkembang bagi memastikan keberadaan imej satelit untuk memenuhi keperluan pengguna remote sensing tempatan. Malangnya, satelit remote sensing tempatan telah menghasilkan imej yang berkualiti rendah. Teknik kalibrasi penggantian boleh dimanfaatkan untuk keperluan pasca kalibrasi bagi mengatasi masalah ini. Bagaimanapun terdapat kekangan menggunakan pendekatan ini dalam menentukan sasaran permukaan yang kukuh. Buat masa ini, pendekatan kalibrasi berdasarkan pantulan telah digunakan untuk pengukuran tetapi terhad dengan menggunakan beberapa tapak ujian sebagai sasaran kalibrasi. Malaysia sebagai negara persekitaran tropika sepatutnya mampu menyediakan permukaan semulajadi yang cukup stabil sebagai sasaran kalibrasi. Tujuan utama kajian ini adalah untuk membangunkan himpunan data spektral bagi ciri spatial yang terpilih. Himpunan data spektral ini akan digunakan sebagai rujukan dalam kalibrasi imej yang dijanakan oleh kamera. Jalur nampak dan jalur hampir infra-merah (NIR) dari imej Landsat 7 dan SPOT XS digunakan dalam kajian ini untuk memperolehi nilai pantulan. Nilai-nilai pantulan ini diperoleh daripada kawasan permukaan air, tumbuhan mampat, ciri buatan manusia dan litupan awan. Lengkungan pantulan untuk setiap fitur dibandingkan dengan himpunan data spektral ASTER sebagai rujukan. Perbandingan ini menunjukkan lengkungan pantulan daripada imej Landsat 7 dan SPOT XS adalah hampir sama dengan lengkungan pantulan daripada himpunan data spektral rujukan. Julat nilai pantulan dari permukaan air adalah diantara 0.018 hingga 0.028, fitur tumbuhan 0.01 hingga 0.5 dan fitur buatan manusia diantara 0.05 hingga 0.4. Fitur awan pula memberikan julat antara 0.2 hingga 1. Taburan statistik bagi pantulan spektral ditentukan untuk mendapatkan hasil nilai min, varians dan sisihan piawai. Nilai-nilai ini digunakan bagi menentukan nilai minimum dan maksimum pantulan spektral untuk setiap fitur. Selang jalur diplot di mana julat paras selang yang rendah menunjukkan nilai pantulan yang diperolehi sesuai digunakan untuk dihimpunkan sebagai pangkalan data spektral tempatan.

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LIST OF ABBREVIATIONS AND SYMBOLS

ANGKASA	-	Malaysian National Space Agency
ARSM	-	Malaysian Remote Sensing Agency
BRDF	-	Bidirectional Reflectance Distribution Function
d^2	-	the square of the Earth-Sun distance in astronomical units
DN	-	Digital Number
EMR	-	Electromagnetic Radiation
$ESUN_\lambda$	-	Mean solar exoatmospheric irradiances
JD	-	Julian Day
JHU	-	Johns Hopkins University
JPL	-	Jet Propulsion Laboratory
L_λ	-	Spectral radiance at the sensor's aperture
$LMAX_\lambda$	-	Spectral radiance scales to QCALMAX
$LMIN_\lambda$	-	Spectral radiance scales to QCALMIN
$L_{Pixel,Band}$	-	Top-of-atmosphere band integrated radiance image
MACRES	-	Malaysian Centre for Remote Sensing
NASA	-	National Aeronautics Space Administration
NEqO	-	Low Earth Near Equatorial Orbit
QCAL	-	Digital Number
QCALMAX	-	the maximum quantized calibrated pixel value
QCALMIN	-	the minimum quantized calibrated pixel value
SSTL	-	Surrey Satellite Technology Ltd
SWIR	-	Shortwave Infrared
TOA	-	Top-of –Atmosphere
USGS	-	United States Geological Survey
ρ	-	Unitless planetary reflectance
θ_s	-	Solar zenith angle in radians

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In 1960's United States begin collection of intelligence photography from earth orbiting satellite. After awhile, Gemini and Apollo space ship were launched for space photography which leads to the development of data acquisition from space. Malaysia foray into this highly specialized field when the plan for the country's space was first put into place. In 1972 the beginning of satellite series of Landsat which offers high-spatial resolution imagery with the longest operation of continuous dataset, open wide opportunities for Malaysia to get involve in data acquisition using satellite. Later, under Planetarium Division in Prime Minister Department, Malaysian Remote Sensing Agency (ARSM) which once recognized as Malaysian Centre for Remote Sensing (MACRES) was established in 1988. This organization was ascertained as research (R&D) centre which divided by application development and technology development. The establishment vision was to lead development in space technology applications especially in remote sensing area in Malaysia.

In the end of 1990, Malaysia gets involved in developing a microsatellite for space mission. The development of satellite technology in Malaysia was largely shaped by the country's National Telecommunication Policy (NTP) which called for Malaysia to have its own satellite. The main body responsible for strategic planning and policy formulation of space related activities is Malaysian National Space Agency (ANGKASA) which works with various agencies, departments, universities and research centre to advance space role in Malaysia towards its vision in harnessing spaces as platform for knowledge generation, wealth creation and society well-being.

Beside the communication satellites, Malaysia developed its own remote sensing satellite system. The first micro-satellite was launched on December 2000 which was named TiungSAT-1. TiungSAT-1 was built by Surrey Satellite Technology Ltd (SSTL) at the Surrey Space centre under programme between the United Kingdom and Malaysia. Its mission objectives are advanced remote sensing and digital store and forward communication. The second remote sensing satellite is RazakSAT which was launched on July 2009. RazakSAT is a cost-effective 180kg mini satellite. Its mission is to ensure the availability of satellite imaging for any part of Malaysia in order to fulfil the requirements of the local remote sensing user community. RazakSAT was placed in a Low Earth Near Equatorial Orbit (NEqO) to improve the constrained by cloud and timeliness. The NEqO enables RazakSAT to provide higher imaging opportunity for Malaysia and other countries that are situated near the Equator. In the other hand, there are several disadvantages of RazakSAT especially in term of its post-launch calibration, which produced low-quality images. The vicarious calibration technique can be adopted to provide post-calibration opportunity. However, this approach has constraints in defining well establishing target bodies where certain criteria and parameter need to be extracted. Calibration target can be generally divided into man-made and natural targets. There are several potential natural targets available for selection such as dark dense vegetation that varies depends on the climate, water bodies that changes based on sediment concentration and cloud cover problems. Cloud detection is easier than water due to the characteristics of water that has identical and low reflectance in the near infrared wavelength but is much complicated on land cover even at high resolution when the clouds are much bigger than the size of pixel. These targets are not randomly distributed that made difficult on selecting sample as test site. In order to overcome these problems, sample size need to be adjusted depends on the area selected. Man-made target is usually selected in open and stable area for example concrete, house or asphalt area.

Satellite sensors are no exception for requiring calibration of the instrument to retrieve a consistent data from physical measurement. Thus special concentration is required to investigate the effect of sensor degradation by incoming radiometric signal. Radiometric calibration consists of two types that are absolute and relative radiometric calibrations. Absolute radiometric calibration was carried out by ratioing the output of digital counts obtained from a sensor with uniform-radiance field value. While relative calibration was resolved by regulating the amounts produced by the detectors to a certain average amount obtained from all the detectors in the band. From this, interband calibration can be referred by describing the relative amount of the average outputs calculated from two or more different bands of a sensor. The difference in this ratio indicates the temporal change occurred in one or more spectral bands. Moreover, stability can be verified from the relative amount of the average outputs from all selected bands and for the similar stable target of different dates. Regularly, relative radiometric calibration is applied for changes more than a few days time due to its high precision. While absolute radiometric calibration is applied with relative radiometric calibration for extensive time due to its greater long-term temporal stability.

1.2 Problem Statement

Currently, calibration capabilities for Malaysian Remote Sensing programs for visible and near infrared band used two ways of conducting radiometric calibration which are pre-flight measurements in laboratories and without on-board calibrate. Accuracy of pre-flight sometimes is dissatisfying due to difficulty in matching the harsh condition that will be encountered while launching and in-orbit. In addition, the instruments are subjected to degradation after launch because of the aging of the optics or of the out gassing which occurs when the instruments leaves the atmosphere. The ultimate result of radiometric calibration will be at-sensor radiance derived from the ground measurement. Reflectance based calibration approach had been used in the measurement. Bare soil is used as the local man-made test site as a calibration target.

The absence of on-board calibration has reduced the reliability of image data observed by MAC on-board the RazakSAT. Normally, the vicarious calibration is employed to provide calibration opportunity for these image data. Stable calibration targets are required to set as a reference for the process. The calibration targets can be of any type that has stable reflectance values of Electromagnetic Radiation (EMR). Natural targets such as snow, water bodies, dark-dense vegetation, cloud bodies and others can be adopted as reference.

In order for a feature to qualify as a calibration target a stable EMR reference values is a must. This has become an inspiration for the proposed study. A comparison approach has been proposed to calculate the EMR reflectance value. A number of natural features have been selected and their EMR reflectance values are analyzed to ensure their stability.

1.3 Objectives

The goal of this study is to develop a spectral library for selected spatial features. The spectral library will serve as a reference for the calibration of the image data generated by the camera. The following objectives are needed to be fulfilled the goal of this study:

a. To select spatial feature and remove all of atmospheric effect.
b. To calculate and correct the reflectance values for selected features that can be utilized as calibration target.
c. To evaluate and validate for stability of the calculated reflectance values for selected spatial features.

1.4 Scope of Study

The selection of natural features to serve as calibration target is based on main natural features in Malaysia that represent the range of targets which are bright, midrange and dark value of data reflectance. The natural targets are classified as three main classes which are water bodies, dark dense vegetation and cloud. Other man made target was selected which consist of building areas. The natural targets were selected as it is the main geographic area covered in Malaysia.

Remote sensing image data of different dates were used in the study. They are from Landsat 7 and SPOT XS. Table 1.1 below shows the remote sensing image data used in this study. Landsat 7 consists of images dated of 5th July 2000, 8th May 2001 and 8th July 2001. SPOT XS consists of images dated of 20th June 2000 and 19th June 2001. These images were used as it partially covered the seasonal changes in Malaysia. The areas covered are from east coast of Peninsular Malaysia, southern of Peninsular Malaysia and coastal of Sabah and Sarawak.

Atmospheric correction model and statistical model were used in this study. The algorithm involved in atmospheric correction model is ATCOR2 and COST algorithm while for statistical model the algorithm used are mean, standard deviation, variance, for every features and confident level for each band. Software involved in processing these data is ERDAS Imagine 2011 where the build in program for atmospheric correction model help for processing SPOT XS images.

Statistical approach is needed for analysis the results. This is based from statistical model and accuracy assessment that had been achieved from spectral reflectance of each remote sensing image with ASTER spectral library.

Table 1.1 Remote sensing image data of various dates

No	Satellite	Date	Region
1.	Landsat 7	5th July 2000	Sabah, East Malaysia
2.	Landsat 7	8th May 2001	East Coast of Peninsular Malaysia
3.	Landsat 7	8th July 2001	Sarawak, East Malaysia
4.	SPOT XS	20th June 2000	East Coast of Peninsular Malaysia
5.	SPOT XS	19th June 2001	Southern Peninsular Malaysia

1.5 Significance of Study

Remote sensing technology in other developed countries grows rapidly for several years in advanced compared to Malaysia. Many of research works in remote sensing technology were carried out in developed countries, this include for extracting spectral reflectance for each spatial feature. There are a number of agencies in developed countries involved in building spectral database system of spatial features which is known as spectral library. Agencies that compile the spectra of natural and manmade materials are Johns Hopkins University (JHU) Spectral Library, the Jet Propulsion Laboratory (JPL) Spectral Library and United States Geological Survey (USGS). This collection includes a series of ultraviolet (UV), visible and near infrared (NIR) of hyperspectral image data such as AVIRIS and ASTER.

In Malaysia, there are only two government agencies that play the important role in remote sensing technology which are Malaysian National Space Agency (ANGKASA) and Malaysian Remote Sensing Agency (ARSM). ARSM especially is the only government agency that provides remote sensing data to other agency and established as research centre in space technology applications especially in areas of remote sensing development in Malaysia.

Until now there is no database system that can be used as a spectral library for spectra natural and manmade features in Malaysia. Vegetation that covers tropical country like Malaysia is different than vegetation in European countries. They are more stable in terms of reflectance characteristics and experienced little seasonal variations over the year. Furthermore Malaysia has its own atmospheric conditions that give impact to the spectral target. Due to these facts, spectral library database from European countries cannot be fully utilized as a reference in Malaysia.

Therefore, a spectral library database for spectra features in Malaysia need to be developed as a reference for image data generated by sensor on-board orbiting platforms, as well as a useful reference for other agencies that involved in application of remote sensing data. In addition, this study help to contribute towards solving the current issues in calibration capabilities for visible and near infrared band.

Study Area

Malaysia with 330 000 km^2 land area and a total population of 28 million in 2010 relatively is a small country. Malaysia consists of three regions that are Peninsular Malaysia, Sabah and Sarawak. Peninsular Malaysia is bounded between Thailand that situated in the north and Singapore which is situated in the south. The country is surrounded by the South China Sea and Indian Ocean. The topography of Peninsular Malaysia is dominated by a mountain range. This mountain range is called Main Range or Banjaran Titiwangsa that runs through the middle of peninsular up to an elevation of about 2000 m above sea level. Many rivers flow towards the flood plains and the coast from this range. The east coast of Peninsular Malaysia is depiction of ridges of sand and river deposits while the west coast of Peninsular Malaysia is dominated by deposits of marine alluvial. As in Figure 1.1, the study area are from the area of east coast and southern of Peninsular Malaysia. The east coast of Peninsular Malaysia consists of coastal of Terengganu and Pahang. The southern of Peninsular Malaysia consists of Johor area. Sabah and Sarawak as in Figure 1.2 is bordered with Indonesia. The topography of Sabah and Sarawak are generally mountainous with almost 70% of Sarawak comprised by very steep areas. Figure 1.2 shows the selected area of southern Sabah which consist of Kalumpang area and coastal Sarawak which consist of Kuching area.

Malaysia lies entirely in the equatorial zone where it is covered by tropical rain forest and characterized by tropical climate. The characteristics of the climate for Malaysia are consistent temperature, high humidity and abundant rainfall throughout the years. The winds in Malaysia’s atmosphere are commonly light and it is infrequent to have a complete day with entirely clear sky even through the time of severe drought. As well it is infrequent to have draw out of a few days with totally no sunlight except for the period of the northeast monsoon terms. There are four seasons can be distinguished based on wind changes; the southwest monsoon, northeast monsoon and two shorter times of inter-monsoon terms. The southwest monsoon season is typically begun in the second half of May or near the beginning of June and ends in September. The northeast monsoon season usually commences near the beginning of November and ends in March. The periods of inter-monsoon seasons are marked by heavy rainfall.

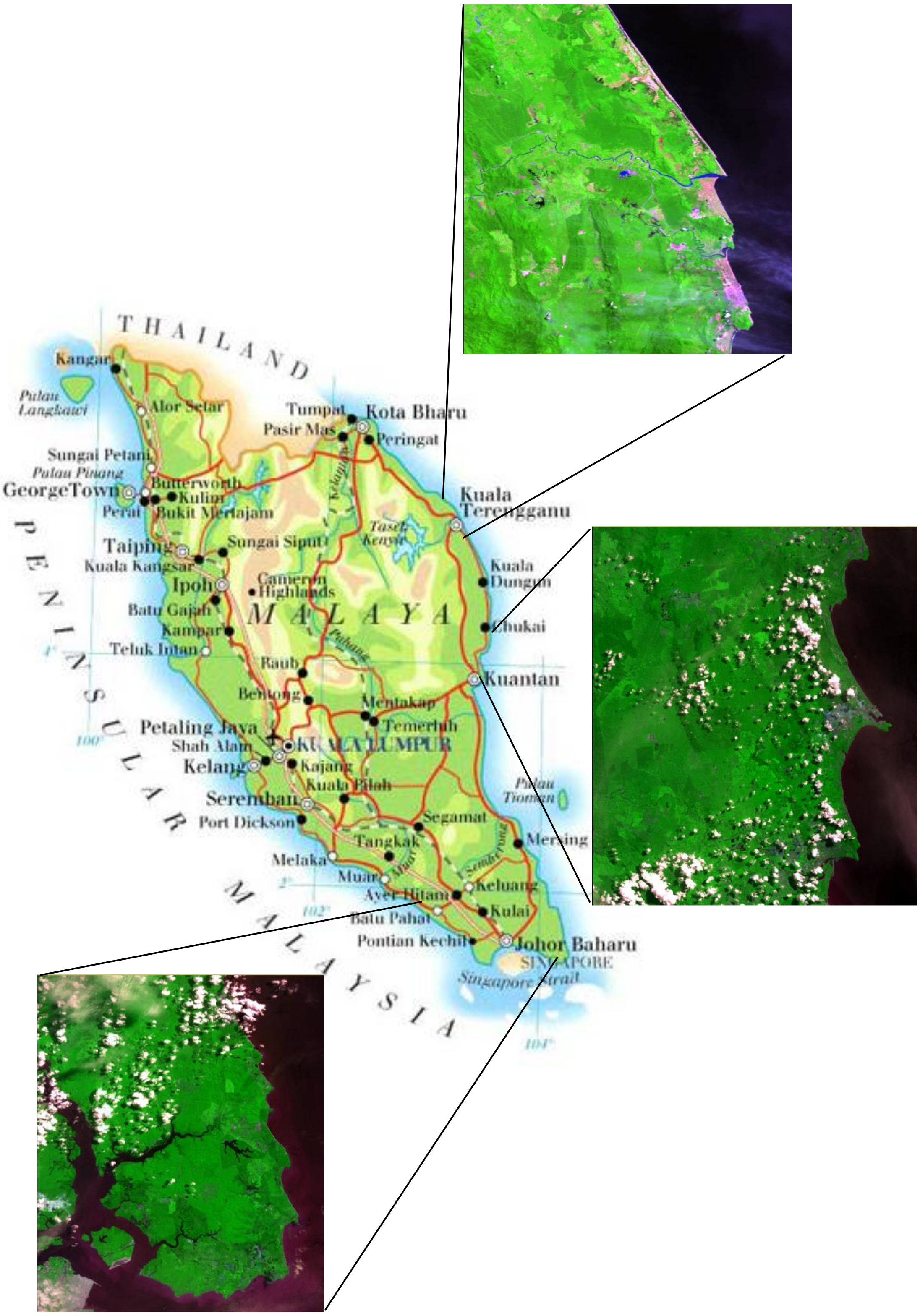

Figure 1.1 Location of study area (Peninsular of Malaysia)

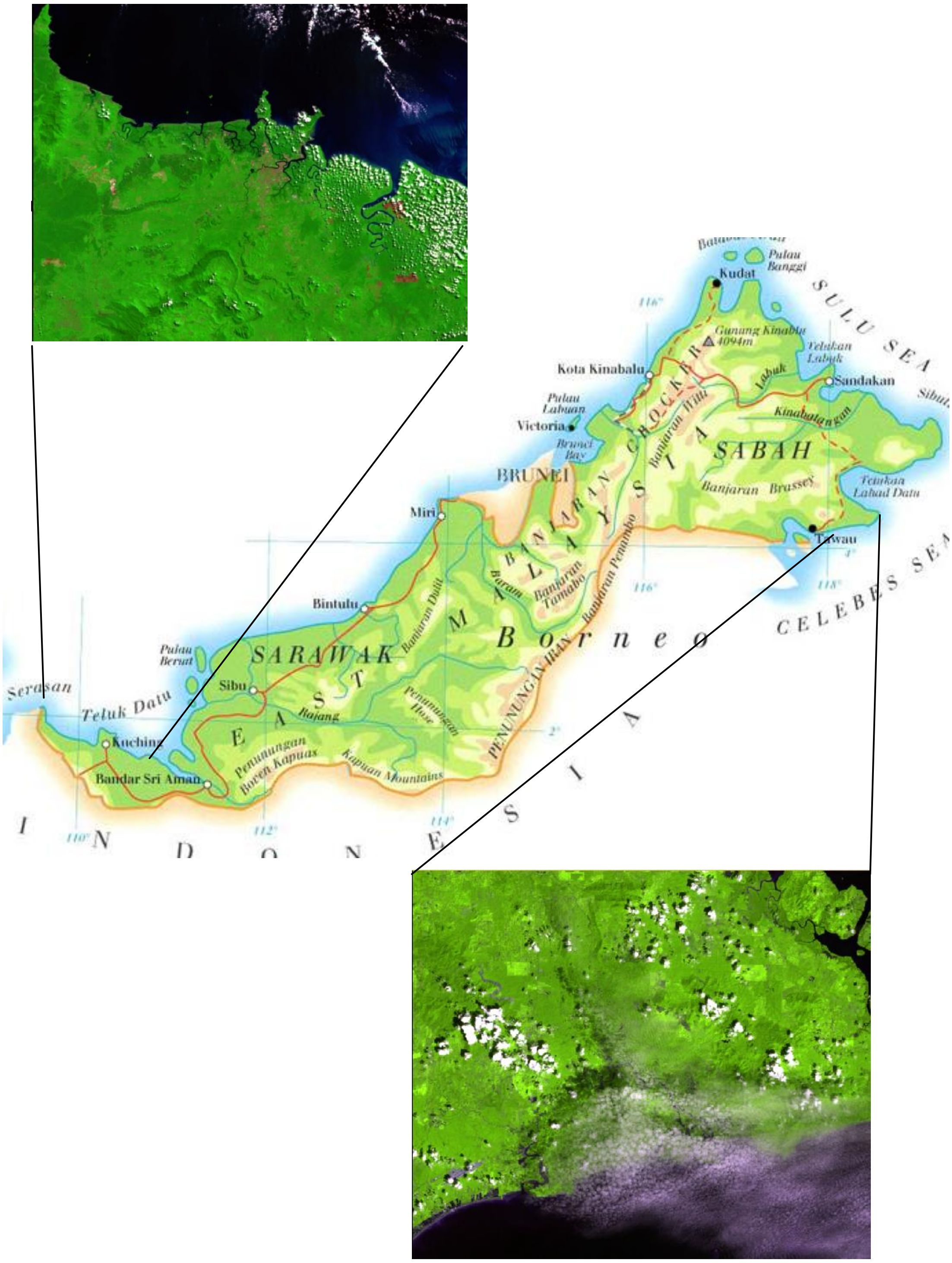

Figure 1.2 Location of study area (East of Malaysia)

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