COMPARATIVE MODEL FOR CLASSIFICATION OF FOREST DEGRADATION

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Thank you.

Sincerely yours,

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This thesis is dedicated to my beloved family, my lovely wife who paid the price during my postgraduate studies.

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ABSTRACT

The challenges of forest degradation together with its related effects have attracted research from diverse disciplines, resulting in different definitions of the concept. However, according to a number of researchers, the central element of this issue is human intrusion that destroys the state of the environment. Therefore, the focus of this research is to develop a comparative model using a large amount of multi-spectral remote sensing data, such as IKONOS, QUICKBIRD, SPOT, WORLDVIEW-1, Terra-SARX, and fused data to detect forest degradation in Cameron Highlands. The output of this method in line with the performance measurement model. In order to identify the best data, fused data and technique to be employed. Eleven techniques have been used to develop a Comparative technique by applying them on fifteen sets of data. The output of the Comparative technique was used to feed the performance measurement model in order to enhance the accuracy of each classification technique. Moreover, a Performance Measurement Model has been used to verify the results of the Comparative technique; and, these outputs have been validated using the reflectance library. In addition, the conceptual hybrid model proposed in this research will give the opportunity for researchers to establish a fully automatic intelligent model for future work. The results of this research have demonstrated the Neural Network (NN) to be the best Intelligent Technique (IT) with a 0.912 of the Kappa coefficient and 96% of the overall accuracy, Mahalanobis had a 0.795 of the Kappa coefficient and 88% of the overall accuracy and the Maximum likelihood (ML) had a 0.598 of the Kappa coefficient and 72% of the overall accuracy from the best fused image used in this research, which was represented by fusing the IKONOS image with the QUICKBIRD image as finally employed in the Comparative technique for improving the detectability of forest change.

ABSTRAK

Cabaran dalam menangani degradasi hutan dan kesannya telah menarik pelbagai penyelidikan dari pelbagai bidang, mengakibatkan definisi terhadap konsep yang berbeza. Walaubagaimanapun, menurut sebahagian penyelidik, elemen utama dalam isu ini ialah pencerobohan manusia yang telah memusnahkan keadaan alam sekitar. Oleh itu, fokus penyelidikan ini ialah untuk membangunkan model perbandingan menggunakan sejumlah besar data remote sensing multi spektrum seperti IKONOS, QUICKBIRD, SPOT, WORLDVIEW-1, Terra-SARX dan data gabungan untuk mengesan degradasi hutan di Cameron Highlands. Hasil dari kaedah ini sejajar dengan model pengukuran prestasi. Ini akan membantu dalam mengenalpasti data yang terbaik, data gabungan dan teknik yang akan digunakan. Sebelas teknik telah digunakan untuk membangunkan Teknik Perbandingan dengan mengaplikasikannya kepada lima belas set data. Hasil dari Teknik Perbandigan telah digunakan untuk membekalkan model pengurusan prestasi supaya dapat memperbaiki ketepatan setiap klasifikasi teknik. Bahkan, model pengurusan prestasi telah digunakan untuk mengenal pasti hasil dari Teknik perbandingan, dan hasil hasil ini telah disahkan menggunakan perpustakaan pantulan. Sebagai tambahan, model konsep hibrid yang dicadangkan dalam penyelidikan ini akan memberi peluang kepada para penyelidik untuk mewujudkan model pintar automatik untuk kerja kerja masa hadapan. Hasil dari kajian ini telah menunjukan Rangkaian saraf (NN) adalah Teknik Pintar (IT)terbaik dengan 0.912 bagi Kapa Koefisien dan 96% bagi ketepatan keseluruhan. Manakala Mahalanobis memperolehi 0.795 Kapa Koefisien dan 88% bagi ketepatan keseluruhan. *Maximum likelihood* (ML) memperolehi 0.598 bagi Kapa Koefisien dan 72% bagi ketepatan keseluruhan daripada imej gabungan yang terbaik dalam kajian ini, yang diwakili dengan menggabungkan imej IKONOS dengan imej QUICKBIRD yang akhirnya digunakan dalam Teknik Perbandingan untuk memperbaiki kebolehkesanan degradasi hutan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABREVIATIONS

AC	-	Atmospheric Correction
AI	-	Artificial Intelligence
AID	-	Automatic Interaction Detection
AIRSAR	-	Airborne Synthetic Aperture Radar
ANN	-	Artificial Neural Networks
ARSM	-	"Malaysia Remote Sensing Agency"
AVHRR	-	Advanced Very High Resolution Radiometer
BP	-	Back Propagation
BRDF	-	Bidirectional reflectance distribution function
CHAID	-	Chi-squared Automatic Interaction Detector
CM	-	Comprative Model
DEM	-	Digital Elevation Models
DTC	-	Decision Tree Classifications
EAs	-	Evolutionary Algorithms
ENVI	-	Environment for Visualizing Images
EO	-	Earth Observation
FFNN	-	Feed Forward Neural Network
FLAASH	-	Fast Line-of-sight Atmospheric Analysis of Spectral Hyper
FLS	-	Fuzzy Logic System
FNN	-	Fuzzy Nearest Neighbour
GA	-	Genetic Algorithms
GCP	-	Ground Control Points
GIS	-	Geographic Information System
GPS	-	Global Position System
GSI	-	Ground Sampling Interval
HH	-	Horizontal transmit and horizontal receive polarizations

HRG	-	High Resolution Geometrical
HRVIR	-	High-Resolution Visible and Infrared
HSV	-	Hue-Saturation-Value
HV	-	Horizontal transmit and vertical receive polarizations
ID3	-	Induction of Decision Tree
HIS	-	Intensity-Hue-Saturation
IK	-	IKONOS
IR	-	Infrared
ISODATA	-	Iterative Self- Organizing Data Analysis Technique
IUCN	-	International Union for Conservation of Nature
KNN	-	k Nearest Neighbor
LAI	-	Leaf Area Index
LULC	-	Land Use and Land Cover
MD	-	Minimum Distance
MLC	-	Maximum Likelihood Classifier
MODTRAN	-	Moderate Resolution Atmospheric Transmission
MS	-	Multispectral
NASA	-	National Aeronautics and Space Administration
NDVI	-	Normalized Difference Vegetation Index
NIR	-	Near Infrared
NN	-	Neural Network
OAA	-	One Against All
OAO	-	One Against One
PAN	-	Panchromatic
PCA	-	Principal Component Analysis
PE	-	Processing Elements
PMM	-	Performance Measurement Model
PNN	-	Probabilistic Neural Networks
PRFs	-	Permanent Reserved Forests
PSO	-	Particle Swarm Optimization
QB	-	Quick Bird
RADAR	-	Radio Detection and Ranging
RBF	-	Radial Basis Function

RMSE	-	Root Mean Square Error
RPC	-	Rational Polynomial Coefficients
ROI	-	Region Of Interest
SAM	-	Spectral Angel Map
SAR	-	Synthetic Aperture Radar
SI	-	Swarm Intelligent
SID	-	Spectral Information Divergence
SM	-	Stripmap mode
SP	-	SPOT
SPOT	-	Satellite Pour "Observation" de la Terre
SVMs	-	Support Vector Machines
TGO	-	Trimble geometrics
TLU	-	Threshold Logic Unit
V	-	Visible
VH	-	Vertical Horizontal
VV	-	Vertical Vertical
WV	-	World View

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Worldwide, forests are very much an important element of the Earth's ecology. Forests play a very critical role in the air composition that living things breathe, provision of environmental diversity, protection of the soil from erosion, and sustaining the water cycle (Bonan, 2008). For instance, forest products are no doubt the main source of living for billions of people and the entire world. Additionally, they minimise greenhouse gas emissions into the atmosphere through the means of carbon repossession. In 2008, Ollingera et al. highlighted that the role forests play in reducing climate change is above expectation. Regrettably, forest cover degradation has become part and parcel of human behaviour in the past decades. The degradation includes, amongst others, cutting down trees, conversion to plantation or cropland as well as man-made or natural catastrophes (Potter et al., 2003). Even though natural catastrophes play a major role in forest degradation, a huge percentage of deforestation is as a result of direct human action in an attempt to increase economic status, and social as well as demographic forces. Anyway, the effects of deforestation can be very big and last for decades (Kumar, 2011).

Remote sensing has a potential role as a source of information in sustainable management around the world. This potential is largely determined by the unique characteristics of remote sensing data which provide synoptic, repetitive, and quantitative and spatially explicit functions (Franklin, 2001). Remote sensing, taking into account the above -mentioned meaning, is a very powerful and promising tool in providing independent data, which can also be used to evaluate forest change (Lucas et al., 2002; Lu et al., 2005).

In the developed countries, remote sensing data helps immensely in development projects, such as creating the appropriate action plans for forest monitoring and forecasting purposes. Changes in Land Use and Land Cover (LULC) as well as forest changes can be detected by utilising remote sensing as the main tool to monitor the local, regional as well as international resources. Remote sensing provides the basis for a better understanding of the relationships between human and natural phenomena (Vahidi et al., 2013).

Remote sensing studies on image classification have become a hotspot topic nowadays by researchers. The remote sensing community considers classification results as benchmarks for several environmental and socio-economic applications. Researchers and practitioners have successfully developed advanced classification strategies and techniques to improve the classification accuracy and reliability (Foody, 1996; Gong et al., 1999; Stuckens et al., 2000; Franklin et al., 2002; Pal and Mather, 2003; Gallego, 2004; Brekke and Solberg, 2005; and Feng et al., 2007). However, the classification of data obtained from the remote sensing technique into a thematic map remains a challenge due to many factors, such as the complexity of the landscape in a given study area, selected remote sensing data, image processing and classification strategies. These factors may cause an incorrect classification.

Digital image classification is primarily based on several algorithms that have the ability to provide an automatic system to successfully determine similarities and distinguish different surfaces. The degree of identification achieved by these algorithms includes an efficient utilisation of the remote sensing data. Accordingly, various algorithms have been developed in an attempt to classify vegetation, forest, Land Use and Land Cover (LULC) etc. In this research, a Comparative Model (CM) was developed to be able to enhance the detectability of forest change. Moreover, a Performance Measurement Model (PMM) was equally employed in this study to check the accuracy of the classification outputs.

Previous researches on image classification as well as the latest reviews of classification methods for tropical region are scarce (Tso and Mather, 2001; Landgrebe, 2003). Based on recent findings, classification algorithms and techniques for forest areas require an intensive review. This will be very valuable for guiding or selecting a suitable classification method for a particular study, as revealed in this research.

The use of Artificial Intelligence (AI) in environmental modelling with recognition of its potential acceptance has increased. AI imitates the human perception, learning and thinking in order to solve complex problems (Chen et al., 2008). This research is based on artificial neural networks, fuzzy models, swarm intelligence, machine learning and hybrid systems in order to improve the Comparative technique used in this research.

Data retrieval from manual and semi-automatic strategies has been greatly affected by the interpreters. But the automatic extraction, so far, depends on the performance of the algorithm as well as the content of the information obtained from the image (Al- Dossary and Marfurt, 2007). Particle swarm optimisation (PSO) is one of the AI techniques improving the performance of Artificial Neural Networks (ANNs). ANNs are used to develop a land use map or other environmental variables, which present with a membership value of 0 to 1. This depends on the degree of closeness of the class for each class used in the training .

1.2 Problem Statements

Despite the growing global awareness of the importance of the conservation of tropical rainforests, the available methods to classify humid tropical forests are not sufficient. Deforestation, degradation and loss of biodiversity would eventually cause negative effects in the livelihoods of people who depend on the forest resources. As Komlos (2008) stated, it is well known that rapid development modifications can significantly degrade the surrounding environment. These development activities manifest as land modifications, such as the conversion of wetlands to settlements and alterations in the land cover in the area. As a result, major changes in the vegetation cover and surface water occur with related implications for productivity and sustainable development in the area. Moreover, these activities result in more occurrences of severe land degradation. It is necessary to seek a detailed understanding of the linkages between the manifestations of land degradation and human settlement intensification through the identification and areal quantification of land modifications associated with land degradation.

Tropical forest regions have suffered from forest degradation, which as a result has brought a major concern amongst the local communities. Particularly, Cameron Highlands have suffered a lot from landslides, erosion, and so on. Previously, there has been no study conducted in the study area with regards to forest degradation detection to monitor forest degradation. To achieve the foregoing, comparative techniques should be the appropriate technique. There is a lack of large original and fused satellite data usage from the previous studies in obtaining a suitable database to be used for the Comparative technique.

Remote sensing classification techniques are faced with difficulties of integrating statistical data classification. The successful use of Artificial Neural Networks (ANNs) with regards to remote sensing has really been encouraged by many previous researchers (Brekke and Solberg, 2005; and Sadly and Faisal, 2011). However, the reliability of the outputs from ANN needs more investigation. The performance measurement of the classification output is the main key to enhance the accuracy of the overall classification. This is another important area that needs further investigation.

Swarm intelligent algorithms, such as PSO, have just recently been highlighted in the theoretical datasets utilising binary or maybe even multiclass strategies. More basic classifier methods just produce an excellent outcome across the evaluation of datasets. In addition, no research projects or scientific studies have recently ended up with records on the subject of employing population-based research strategies to optimise the feed forward neural network, FFNN. Development of a new mathematical model is necessary to map highly located forest cover change, such as in Cameron Highlands.

1.3 Study Area

The study area was in the mainland of Cameron Highlands (4° 28' N) (101° 23' E), Pahang, Malaysia. It is located on the main range of Peninsular Malaysia as shown in Figure 1.1 It covers a total area of 71 000 715 km² (Fortuin, 2006). Generally, the terrain is mountainous and strongly dissected with 10–35° slopes. More than 66 percent of the land has a gradient of more than 20°. Cameron Highlands is about 715 km² in area settled between roughly 900 and 1800 m and surrounded by forested peaks rising to 2032 m. The Malaysian lowlands are heavily disturbed, so upland forests like those of Cameron Highlands are an important refuge for biodiversity. Cameron Highlands is significantly cooler than Malaysia’s lowlands, with a mean daily minimum of 14.8ºC, a mean daily maximum of 21.1ºC, which suits temperate crops. The rainfall averages 2660 mm yr-1, humidity is high and there is no marked dry season.

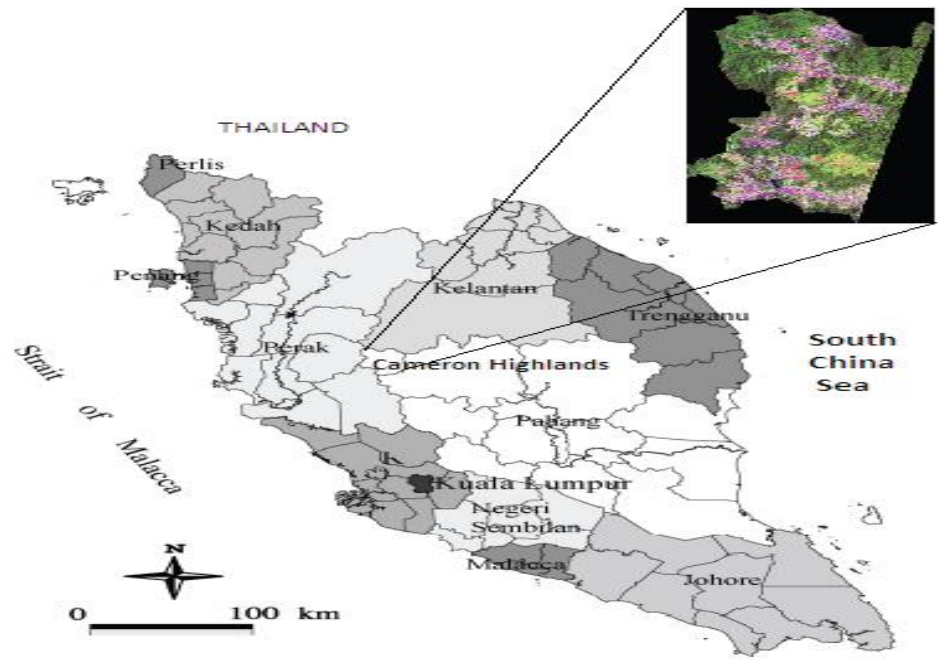


Figure 1.1 Map of the study area (Ismail et al., 2012)

In peninsular Malaysia, Cameron Highlands is a tourist resort and it is referred to as the ‘Green Bowl’ which is the second most important state for growing vegetables (mostly cabbage, tomatoes, and leafy vegetables) and is also important for tea, flowers and fruit. In addition, the Cameron Highlands Catchment area is a source of water supply to many areas of Peninsular Malaysia. Sg. Telom, Sg. Bertam and Sg. Lemoi are the three main rivers of the Cameron Highlands Catchment, which drains the northern, middle and southern sections of the highlands (Makalahmad et al., 2008). Cameron Highlands is located approximately 200 km north of Kuala Lumpur on the east side of the border between the states of Perak and Pahang in Malaysia as shown in Figure 3.4. At about 1,500 meters above sea level, it is the highest area on the mainland stretching along a plateau set. Cameron Highlands was named after William Cameron, a British Government surveyor who discovered it in 1885 whilst on a mapping expedition. However, he failed to mark his discovery and it was not until 1925 that Sir George Maxwell recorded Cameron’s discovery and decided to develop it as a hill resort. (Tenaga National Berhad Research, 2009). Cameron Highlands covers from Brincang town, down to Habu. The location of the study area is shown precisely in the data acquisition section. The study area consists of the Mentigi forest reserve, which is one of the gazetted forest reserves in Malaysia. This study area includes various types of land uses, such as forest, urban, tea and vegetable. The choice of this area was due to encroachment issues by the vegetable farmers and illegal logging.

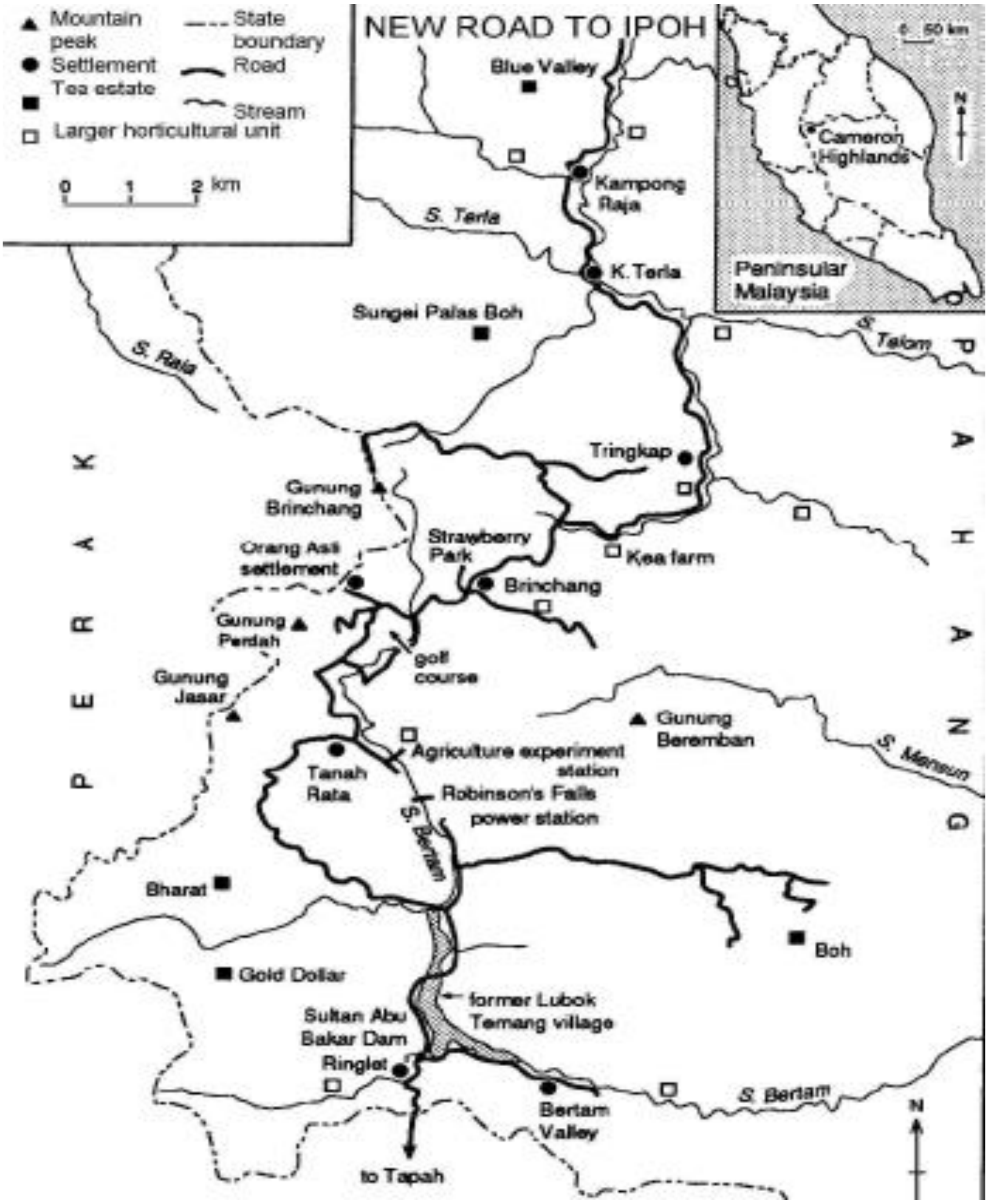


Figure 1.2 The location of Cameron Highlands, located between Perak and Pahang (Malaysian Journal of Environmental Management (Barrow et al., 2005)

1.4 Research Objectives

The general aim of the research has been to develop a Comparative technique for classification of forest degradation. The research has the following sub-objectives:

1. To assess the reliability of optical and radar remote sensing data for monitoring the current situation of forest degradation.
2. To develop a Performance Measurement Model (PMM) that can assist to examine as well as improve the efficiency of the remote sensing data.
3. To establish a new conceptual classifier model using hybrid PSO methods with FFNN.

1.5 Research Questions

The following questions were addressed by this study in order to categorise and map the procedures of forest change:

1. What is the efficiency of using optical, radar, and fused remote sensing data in monitoring and assessing forest degradation?
2. Are the results obtained from the Performance Measurement Model in line with the results obtained from the Comparative Model?
3. How does the hybrid technique help in detecting forest degradation?

1.6 Scope of the Research

In achieving the study's objectives, the scope of the study was designed to carry out a research case study along with the classification framework within satellite remote sensing data to determine suitable strategies coupled with obtaining a better understanding for the purpose of establishing a Comparative technique for Classification of Forest Degradation.

1. In order to develop and test the methodology, the study area has been selected in Malaysia where the preservation of forest process is in practice.
2. The case study area was classified by optical, radar and fused images by using a Comparative model. The results have been compared and evaluated with the traditional classification methods, such as parallel pipe, minimum distance, and so on.
3. The research has mainly emphasized the utilisation of artificial neural networks trained with multispectral values to forecast forest degradation. The advantage of the proposed technique is that it needs very few variables and very little facts.
4. Sensitivity analysis/validation has been carried out in order to check the model's efficiency using a confusion matrix.

1.7 Significance of Research

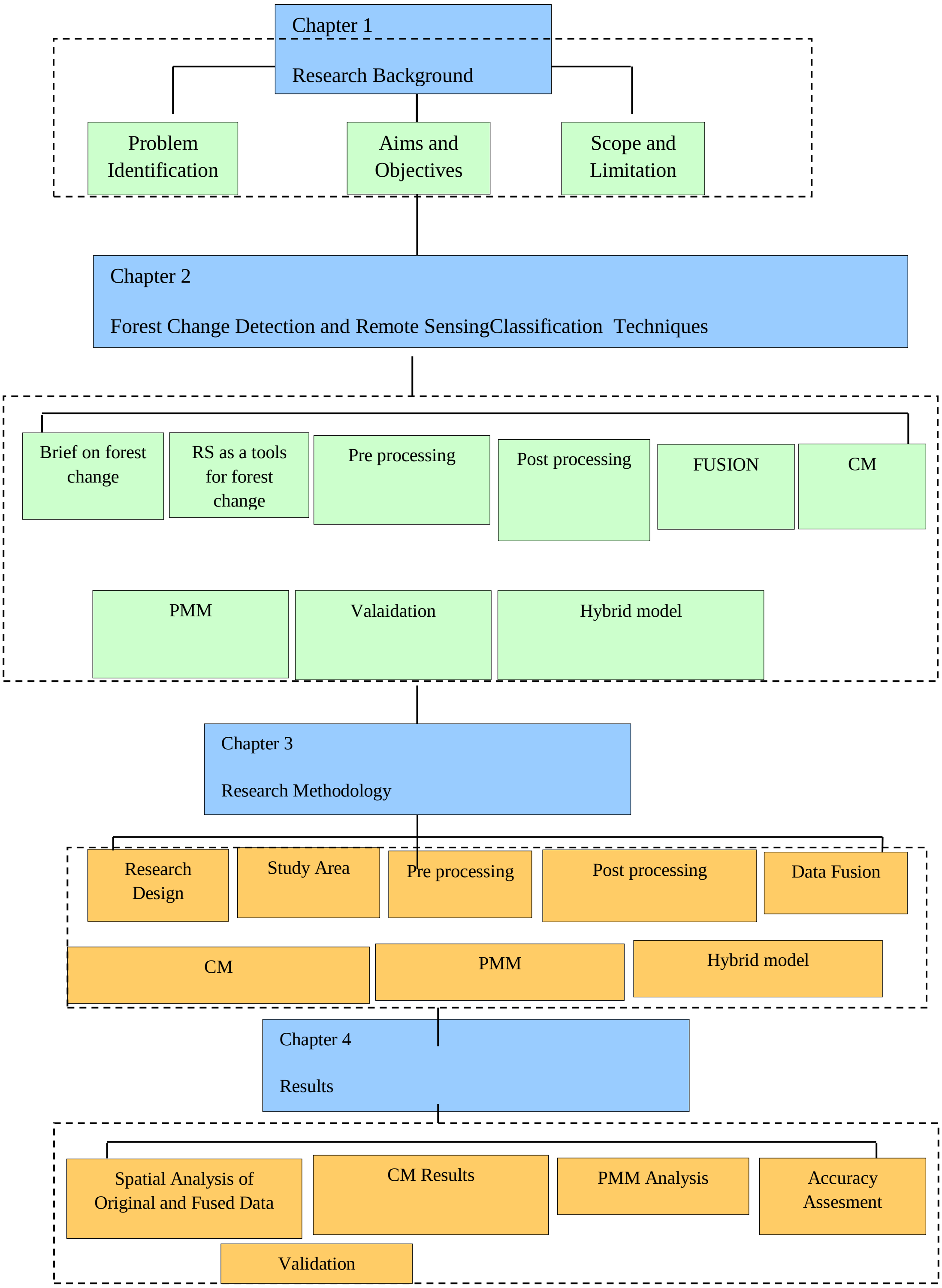
Considering the current availability of satellite images, the variety of Passive and Active sensors provides the ideal possibility of effective tropical forest observation. The initial strategy is going to enhance the Cameron Highlands with data which are readily available from Optical sensors such as IKONOS, QUICKBIRD, SPOT, WORLDVIEW, and TERRASAR-X data. Therefore, these varieties will also provide significant methods which have more tendency of discovering the forest degradation. This kind of multi-sensor strategy has already been developed in this research for beneficial achievement specifically in the situation where the multi-sensor data can be merged together to get more data which is known as image fusion. This will generate more data and enhance the outcome provided by the Comparative technique. Definitely, this research will be useful to several industries to obtain information and facts when dealing with a particular research location.

Moreover, the Comparative Classification Model used in this study including various supervised and unsupervised classification techniques applied on a large amount of optical and radar data of the humid forest has never been published going by the several past studies as in (Kumar, 2006; Shaoqing and Lu, 2008; Rozenstein and Karnieli, 2011; Veettil and Zanardi, 2012; Kalra et al., 2013; Janardhana and Venugopala, 2014; and Mallinis et al., 2014). All the above mentioned studies did not use a large amount of data or many techniques to enhance the classification output. Due to the shortage of specific information and facts, there were serious complications which did not even allow multispectral satellite images to be used. This research has efficiently established a Comparative Model which includes various kinds of data as believed to play the role of benchmark information and facts for forest degradation detection in different humid tropical rainforest and mountainous regions. On the subject of employing population-based research strategies to optimise a feed forward neural network, FFNN, as stated in the problem statement, a conceptual model has been developed. The development of this conceptual intelligent model based on a hybrid of AI and swarm intelligent techniques will help researchers and decision makers in enhancing the outputs from the classification maps. Hopefully, it can come into reality in the near future.

1.8 Thesis Organisation and Flow Chart

The organisation of this thesis is shown in Figure 1.1. In chapter 1, general information on the research, research background, problem description, research aim and objectives, research questions, scope of the research, significance of the research and general organisation of this thesis have been discussed. Chapter 2 contains detailed information on forest changes, locally and globally, and a literature review on forest change detection using remote sensing and Artificial Intelligent techniques. Moreover, the components of the Comparative Model (CM) are discussed. The Performance Measurement Model (PMM) is introduced. Specific techniques of forest change detection utilised in this thesis are discussed and the rationale for selecting this set of techniques is offered.

In chapter 3, the research methodology is discussed. The processes of data acquisition, derivation, and spatial classification of the forest change detection are thoroughly explained. The classification techniques used in this research, the CM and PMM mathematical models are discussed in detail. Moreover, in chapter 4, the results from the fusion, CM and PMM are presented and discussed. The various classification techniques are tested and discussed; and the best classification techniques are identified. The validation of the CM was performed using the PMM and reflectance library. Chapter 5 discusses the main findings including the contribution to the body of knowledge, recommendations, and future research direction.


Chapter 1
Research Background
Problem Identification
Aims and Objectives
Scope and Limitation
Chapter 2
Forest Change Detection and Remote SensingClassification Techniques
Brief on forest change
RS as a tools for forest change
Pre processing
Post processing
FUSION
CM
PMM
Valaidation
Hybrid model
Chapter 3
Research Methodology
Research Design
Study Area
Pre processing
Post processing
Data Fusion
CM
PMM
Hybrid model
Chapter 4
Results
Spatial Analysis of Original and Fused Data
CM Results
PMM Analysis
Accuracy Assesment
Validation

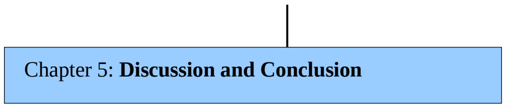


Figure 1.3 Thesis Organizational Flow Diagram

1.9 Summary of the Chapter

The alarming and persistent occurrence of forest degradation, which affects the forest in Cameron Highlands, has caused tremendous damages and distortions to human lives, economics, and properties. Since forest degradation takes place across natural landforms that possess some specific geomorphology and geological makeup, there is an ultimate need to thoroughly examine the study area in order to investigate and analyse the nature of forest degradation. One has yet to see any published article that has used the Comparative Model for the classification of forest degradation challenges in Cameron Highlands. This is detrimental to the populace and their lives as a whole because a more effective tool ought to be used in order to minimise to the maximum the alarming forest degradation epidemic in the area.

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