EVALUATION OF LAND COVER CHANGES IN SULTAN AZLAN SHAH DAM CATCHMENT USING REMOTE SENSING TECHNIQUES

by

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LIST OF ABBREVIATIONS

AOI	Area of Interest
ARSM	Malaysian Remote Sensing Agency
DEM	Digital Elevation Model
DN	Digital Number
GIS	Geographic Information System
GCPs	Ground Control Points
IHS	Intensity-Hue-Saturation
ISODATA	Iterative Self-Organizing Data Analysis
JPSM	Forestry Department Peninsular Malaysia
$\widehat{K}$	Kappa Statistics
LAP	Lembaga Air Perak
LULC	Land Use and Land Cover
MLC	Maximum Likelihood Classifier
MS	Multispectral
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared
OIF	Optimum Index Factor
PCA	Principal Component Analysis
PCC	Post-Classification Comparison
RCC	Roller Compacted Concrete
RGB	Red Green Blue
RMSE	Root Mean Square Error
RSO	Rectified Skew Orthomorphic
SASD	Sultan Azlan Shah Dam
SEPM	Soil Erosion Potential Modeling

SPCA	Selective Principal Component Analysis
SPOT	Satellites Pour I'Observation de la Terre
TM	Thematic Mapper
XS	Multispectral Mode

PENILAIAN TERHADAP PERUBAHAN LITUPAN TANAH DALAM KAWASAN TADAHAN AIR EMPANGAN SULTAN AZLAN SHAH DENGAN MENGGUNAKAN TEKNIK-TEKNIK PENDERIAAN JAUH

ABSTRAK

Kajian ini berkaitan dengan menganalisis corak perubahan litupan tanah di kawasan empangan Sultan Azlan Shah (SASD) dalam tempoh 14 tahun dengan menggunakan data penderiaan jauh terkini. Satelit SPOT XS bertarikh 15 Januari 1996, SPOT 4 MS bertarikh 10 Februari 2002 dan SPOT 5 MS bertarikh 20 Februari 2010 telah digunakan untuk menghasilkan peta pengkelasan litupan tanah. Kaedah pengkelasan tak diselia, diselia dan hibrid telah digunakan dalam proses pengkelasan. Selanjutnya, pasca-pengkelasan pemprosesan telah digunakan pada peta pengkelasan hibrid yang mana telah menghasilkan peratus ketepatan yang tertinggi. Kemudian, pasca-pengkelasan perbandingan (PCC) telah digunakan untuk menganalisis perubahan dalam litupan tanah. Keputusan menunjukkan bahawa menggunakan kaedah pengkelasan hibrid telah menghasilkan peratus ketepatan keseluruhan yang tertinggi untuk imej 1996, 2002 dan 2010 iaitu 77.60% ($\widehat{K}$=0.7267), 80.91% ($\widehat{K}$=0.7456) dan 80.00% ($\widehat{K}$=0.7267). Perlaksanaan pasca-pengkelasan pemprosesan telah menambah baik keputusan pengkelasan kepada 81.82% ($\widehat{K}$=0.7541), 83.18% ($\widehat{K}$=0.7754) dan 83.64% ($\widehat{K}$=0.7926). Peta klasifikasi menunjukkan peratus kawasan yang tertinggi adalah hutan bawah montane (44.98% pada 1996, 45.09% pada 2002 dan 45.81% pada 2010), diikuti oleh hutan dipterokarpa atas (39.15% pada 1996, 38.12% pada 2002 dan 37.02% pada 2010), hutan dipterokarpa bukit (15.41% pada

1996, 14.94% pada 2002 dan 15.04% pada 2010), tanah tandus (0.21% pada 1996, 1.31% pada 2002 dan 1.27% pada 2010), tanah lapang (0.15% pada 1996, 0.44% pada 2002 dan 0.15% pada 2010) dan kemudiannya air (0.11% pada 2010). Dalam tempoh 14 tahun (1996-2010) kawasan hutan telah berkurangan sebahagian besarnya akibat daripada penukaran tanah hutan kepada air, tanah tandus dan tanah lapang. Sebanyak 79,52 ha, 174 ha dan 20.52 hektar tanah hutan telah ditukar kepada air, tanah tandus dan tanah lapang dalam tempoh masa ini. Sumbangan utama perubahan ini adalah disebabkan oleh pembinaan jalan raya Simpang Pulai-Cameron Highland yang bermula pada tahun 2001 dan siap pada tahun 2004 yang merentasi bahagian tenggara kawasan tadahan air SASD, serta pembinaan SASD (siap dibina pada tahun 2006) di bahagian barat laut kawasan tadahan.

EVALUATION OF LAND COVER CHANGE IN SULTAN AZLAN SHAH DAM CATCHMENT USING REMOTE SENSING TECHNIQUES

ABSTRACT

The study deals with analyzing of the land cover change pattern in the Sultan Azlan Shah (SASD) catchment over a period of 14 years using updated remote sensing data. SPOT XS with acquisition date at 15 January 1996. SPOT 4 MS with acquisition date at 10 February 2002 and SPOT 5 MS with acquisition date at 20 February 2010 were used to generated land cover classification map. Unsupervised, supervised and hybrid classification methods were implemented in the classification process. A further post-classification processing was applied to the hybrid classification map which has produced the highest accuracy. Subsequently, post-classification comparison (PCC) was used to analyze the change in land cover. The results shows that using hybrid classification method produced highest overall accuracies for image 1996, 2002 and 2010 which were 77.60% ($\widehat{K}$=0.7267), 80.91% ($\widehat{K}$=0.7456) and 80.00% ($\widehat{K}$=0.7267). Applying post-classification processing further improved the classification results to 81.82% ($\widehat{K}$=0.7541), 83.18% ($\widehat{K}$=0.7754) and 83.64% ($\widehat{K}$=0.7926). The classification map reveals that the highest percentage area were under lower montane forest (44.98% in 1996, 45.09% in 2002 and 45.81% in 2010), followed by upper dipterocarp forest (39.15% in 1996, 38.12% in 2002 and 37.02% in 2010), hill dipterocarp forest (15.41% in 1996, 14.94% in 2002 and 15.04% in 2010), barren land (0.21% in 1996, 1.31% in 2002 and 1.27% in 2010), rangeland (0.15% in 1996, 0.44% in 2002 and 0.15% in 2010) and then water body

(0.11% in 2010). During 14 years span period (1996-2010) the forest area has decrease mainly due to the change of forest land to water, barren land and rangeland. About 79.52 ha, 174 ha and 20.52 ha of forest land were converted to water, barren land and rangeland, respectively, during these periods. The major contribution of these changes are caused by the construction of Simpang Pulai-Cameron Highland road project which began in 2001 and completed in 2004 in which crosses the south-eastern part of SASD catchment, as well as the construction of SASD (completed develop in 2006) at the north-western part of the catchment.

CHAPTER 1

INTRODUCTION

1.1 Background

Land cover refers to the observed (bio)physical cover on the earth's surface, including water, vegetation, barren land and man-made features (FAO, 2000). The continuous rapid change on the land influencing human activities resulting in catastrophes that causes various great impacts on the ecosystem (Vitousek et al, 1997). For instance in watersheds, deforestation associated with land conversion for agriculture, industrial or urbanization purposes can increase soil erosion, leading to impacts on soil and water quality, species composition, and flood intensity (Shi et al, 2012; Gregersen et al, 2003). The detection of these changes is extremely important in providing information with regards to what and where the changes have occurred and analyze these changes to formulate proper mitigation measures and efficient conservation strategies (Santillan et al, 2010).

Satellite remote sensing are widely used as data sources for detection, identification, mapping and monitoring of land cover patterns and changes because of its repetitive coverage at short intervals and consistent image quality (Baldyga et. al, 2004; Lunetta and Elvidge, 1999; Singh, 1989). Current land cover information can be extracted efficiently and cheaply in order to inventory and monitor the changes effectively (Mas, 1999). Remote sensing based change detection involves the use of several images with different acquisition dates to evaluate the changes occurs in land cover due to various human actions and environmental conditions (El-Kawy et al, 2011).

Among the common uses of the change detection techniques using remote sensing data, the post classification comparison (PCC) has been recognized as the most accurate change detection techniques and presented the advantage of indicating the nature of the changes (Reis, 2008; Mas, 1999). PCC technique, detects land cover changes by comparing independently produced classifications of images from different dates (Singh, 1989). It minimizes the problems associated with multi-temporal images recorded under different atmospheric and environmental conditions (El-Kawy et al, 2011). The degree of success of PCC techniques depends on the accuracy of land cover map thus preparing accurate land cover is critical for correct change detection (Rahdary et al, 2008).

Geographic Information Systems (GIS) have become essential tools for handling spatial data (Gao, 2009). Advancement in remote sensing technology (which can provide a large volume of spatial data), along with declining costs of computing system (hardware and software) has made GIS affordable to not only complex environmental/spatial situation but also affordable to an increasingly wider audience (Muzein, 2006). Integration of GIS and remote sensing provides a suitable platform for multiple data type storage, raster data manipulation and analysis, derivation of GIS data from remotely sensed data and as guideline for image analysis to extract more accurate information from spectral data (Miller and Rogan, 2007).

1.2 Problem Statement

Sultan Azlan Shah Dam (SASD) catchment has experienced changes in land cover due to Simpang Pulai-Cameron Highlands Road Project in 2001 which crosses the catchment at the highland regions. These changes have resulted in modification and alteration in the status of land cover and cause increased upland erosion and higher concentrations of suspended sediment within the catchment. The upland erosion had affected water quality in the Kinta River which flows into the SASD reservoir. It also had affected the storage capacity of SASD reservoir due to sedimentation. These environment impacts can reduce SASD performance as its main function is for supply water to meet the demand needed for Ipoh.

Previous studies by Bawahidi (2006) and Mandana (2013) in the Ulu Kinta catchment using remote sensing technique for land use and land cover (LULC) analysis. The Ulu Kinta catchment is a large catchment area which includes the SASD watershed. Bawahidi (2006) had analyzed LULC change within the Ulu Kinta catchment from 1991 to 2004 using satellite Landsat and SPOT data. The change detection study by Bawahidi (2006) was made before the construction of SASD. Mandana (2013) has developed LULC maps for the Ulu Kinta Catchment in 2010 using satellite SPOT-5 data. The lack of understanding of the current trends in land covers change in the SASD watershed has impacted the planning process. Analyses of these changes are essential to provide basic tool for SASD catchment management in order to formulate efficient conservation strategies. Therefore, this study is necessary to evaluate the impacts of land cover changes in the catchment using new remote sensing data.

1.3 Aim and Objectives

1.3.1 Aim

This study aims to analyze the land cover change pattern in the Sultan Azlan Shah Dam (SASD) catchment over a given period, using remote sensing techniques.

1.3.2 Objectives

The following specific objectives will be implemented to achieve the aim stated above.

i. To develop a land cover classification map for Sultan Azlan Shah Dam (SASD) catchment using remote sensing data.

ii. To evaluate the land cover changes in the SASD catchment using multi-temporal SPOT images and post-classification change detection techniques.

iii. To conduct a land cover changes analysis for the catchment.

1.4 Study Area

1.4.1 General Description

The selected area of study is the Sultan Azlan Shah Dam (SASD) catchment is located approximately 12 km east of Kinta District, in the State of Perak, Peninsular Malaysia. The area lies in between latitudes 4°33’30” to 4°41’30’’ North and longitudes 101°22’45’’ to 101°13’0’’ East as shown in Figure 1.1. The SASD catchment is approximately 142 km^2 in area is a sub- catchment for the Kinta River catchment.

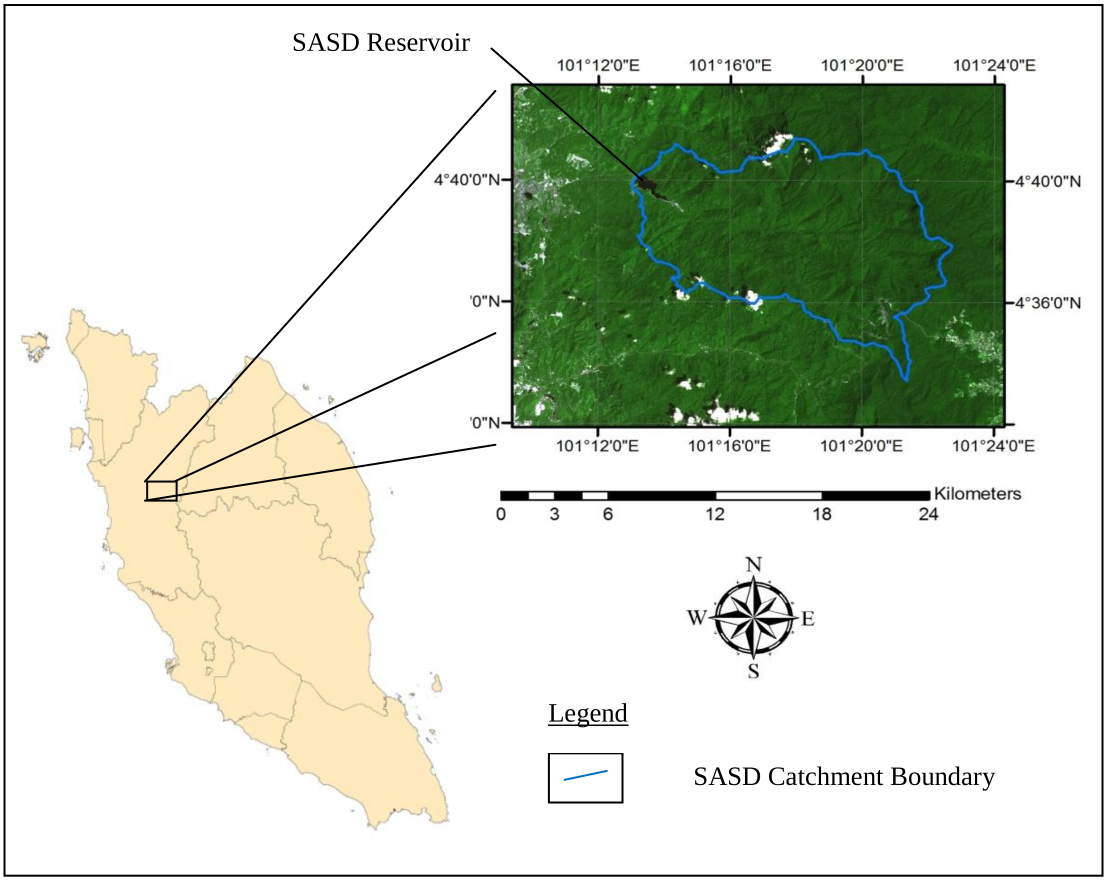

Figure 1.1 Location of the study area in Peninsular Malaysia Map

1.4.2 Topographic and Soil

The SASD catchment is mountainous tropical rainforest area with terrain elevation between 200m to 2183m (Topographic Map of Sungai Siput Utara, 2002; Topographic Map of Cameron Highland, 1994; Topographic Map of Ipoh, 1991; Topographic Map of Gunung Korbu, 1986). The hilly area is covered by forest and the flat area is covered by water, barren land and rangeland. The hills and steep mountains contains of the red-yellow podzolic soils with lithosols on acid to intermediate igneous rocks while the plains land and low terraces contains of alluvial soils and gley soils (Soil Map of Peninsular Malaysia, 1970).

1.4.3 Sultan Azlan Shah Dam (SASD)

The SASD is located northwest of the study area is the first Roller Compacted Concrete (RCC) dam constructed in Malaysia. The SASD was completed on November 2006, which is designed to create storage of 29.9 million m^3 to supply 312Mld of raw water to the new treatment plant (227Mld) and existing Ulu Kinta treatment plant (85Mld) (Huat, 2006).

The dam height of 90m is a straight axis gravity structure about 800m long with a vertical upstream face and a uniform downstream face sloping at 0.75h: 1.0v from the crest. The reservoir covers about 101 ha at the full supply level along the Kinta River and had the maximum and minimum water level of 245.0m and 189.8m respectively (LAP, 2012).

1.4.4 Climatic

The study area has a hot humid tropical rainforest climate. The average annual rainfall in the catchment is approximately 2500 mm and is well distributed throughout the year. The monthly rainfall pattern shows two periods of maximum rainfall separated by two periods of minimum rainfall. The primary maximum rainfall generally occurs in October to November while the secondary maximum generally occurs in April to May (JMM, n.d.).

The temperature in the study area has the highest average annual temperature of 35 °C in March and the lowest average annual temperature of 22 °C in January, whilst the mean daily temperature during was 27 °C (JMM, n.d.).

1.4.5 Land Cover Types

The land cover characteristics of the study area were surveyed through field visits, topographic maps, land use maps and a high resolution SPOT Pan-Sharp image to assist in an image interpretation and for reference data compilation. The study area divided by four major land cover types: water, barren land, rangeland and forest.

Figure 1.2 shows the land cover types founded in the study area. Forest is the major land cover types found in the study area. This forest belonged to Bukit Kinta reserved forest is mostly dominated by trees from Dipterocarpaceae family, hence the term 'dipterocarp forests' (JPSM, n.d).

The water bodies in the study area include SASD reservoir and rivers. The watershed drained the water to the SASD reservoir through Ulu Kinta river system and its tributaries. These water bodies are main source of water for city of Ipoh in domestic and industrial usage.

Rangeland is an area covered by predominantly grasses, shrubs and forbs. The rangeland type's vegetation grows primarily native vegetation, rather than plant established by humans on the land left fallow for a certain period of time. In the study area, it can be discovered in wasteland area following removal of forest tree for road and dam development previously.

Barren land has been defined as non-vegetation cover area consists of road, soil, sand, and rocks. The sand mining activities and Simpang Pulai to Cameron Highland road in study area are mostly contributed to barren land area.

Figure 1.2(a) Dense forest area

Figure 1.2(b) SASD reservoir

Figure 1.2(c) Rangeland area with mixed vegetation

Figure 1.2(d) Barren land area in sand mining sites route

1.5 Organization of Dissertations

This thesis is organized in five chapters. Chapter one which is the current chapter which briefly discusses about the background, problem statement, aim and objectives and study area related to the research study. Following this chapter, a comprehensive literature is reviewed in chapter two. Chapter three describes the methodology adopted to conduct the research. The fourth chapter presents the results of the research with some of the discussion. Finally, the last chapter concludes the research and state the recommendation for the future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature on land cover change in catchment using remote sensing and GIS technologies. It also explained some concept and definitions of processing techniques conducted in the studies.

2.2 Land Cover Change in Watershed

Meyer and Turner II (1992) defined land cover change as “an alteration of the land surface and its biotic cover”. They also stated that changes in land cover takes place in two forms; conversion from one category of land cover to another and modification of condition within a category. For instance, the ‘conversion’ will be the complete changes of a forest area into a built up area while ‘modification’ are change of the primary to secondary forest area.

According to Seto et al (2002), the changes in land cover can be divided into qualitative and quantitative changes. Qualitative changes occur either as natural phenomena (wildfires, lightning strikes, storms, pests) or can be induced by human activity (selective logging, agroforestry). Quantitative change is more broadly categorical transformation of the land, in which replacement with a large scale of land cover type by another, and it can occurs as natural phenomena as caused by fires and storms or by human driving forces (forest clearing, agricultural expansion, urban growth) as well.

The human factors in modifying the land cover are at unexpected rates, magnitudes and spatial scales (Turner II et al, 1994). Human still remains a major cause even though the natural environmental phenomena factors also account for land cover changes (Vitousek et al, 1997). Torahi and Rai (2011) in their study of land cover classification and forest change analysis using satellite imagery noticed that Dehdez area of Zagros Mountain in Iran had faced increasing rates of deforestation due to infrastructure development, new settlement, fuelwood and timber extraction, fodder and grazing. Another study by Li et al (2006) showed that the urbanization had greatly altered the land cover patterns of the largest urban lake watershed in China in a considerably short period of time. These human driving forces originate from the social, economic, and political processes embedded in human societies, and resulted in changes in the demand and supply of land (Kates et al, 1990; Napton et al, 2010).

A watershed is the area of land that feeds water to a river, through the process of precipitation draining through the landscape, into tributaries and into the main river channel (Smith et al, 2006). Change in land cover due to human interaction pose negative impacts to watershed ecosystems (Santilan et al, 2010). It accelerates soil erosion lead to environmental damage in watershed through sedimentation, pollution and increased flooding (Shi et al, 2012). Furthermore, the sedimentation can reduce the reservoir storage capacity in turn affects the economic development of the country because of the role of the reservoir in water supply, flood control, irrigation, electricity generation, recreation, and others (Synder et al, 2004).

The information of land cover change is very crucial for any kind of sustainable program (El-Kawy, 2011). Detection of land cover changes in watershed can provide information with regards to what factor causes, and where, the changes have occurred (Santilan et al, 2010). Such information can help in enhancing the capacity of local governments to implement sound environmental management (Amit et al, 2012). In addition, proper mitigation measure and rehabilitation strategies can be carried out by analyzing the changes (Santilan et al, 2010). A healthy watershed is significant which provide many ecosystem services (water storage, nutrient cycling, recreation, food and timber, carbon storage etc.) that are necessary for social and economic well-being (EPA, 2012).

2.3 Application of Remote Sensing Technology in Land Cover Change

Application of remote sensing technology has become a vital role in the study of land cover change (Boriah et al, 2008). Since the launch of the first Earth Resources Satellite Landsat-1 in 1972, remote sensing has been used extensively in collecting land cover information from the surface of the earth (Gibson, 2000; Lillesand and Kiefer, 1994). Remote sensing offers the capability to monitor a wide range of landscape biophysical properties in less time comparison to *in-situ* monitoring systems (McVicar et al, 2003). Recent land cover information can be extracted efficiently with low cost from remote sensing images which allow monitoring the changes in land cover effectively (Baldyga et al, 2004; Mas, 1999).

According to Lillesand and Kiefer (1994) the term ‘remote sensing’ is the “science and art of obtaining information about and object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation”. Remote sensing systems operate based on measurement of electromagnetic energy, in which the sensors measures the energy that is reflected or backscattered by the earth's surface (Gibson, 2000). Each type of earth surface reflects visible and infrared light in different ways (see Figure 2.1). Water for example absorbs near infrared and reflects a fair amount of green light (Vincent, 1997). Vegetation transmitted and reflected most of the light in the near-infrared with little absorption (Jackson and Huete, 1991). Thus, the knowledge of the spectral reflectance patterns of various land cover features on the earth surface is significant for interpretation of remote sensing images (Navalgund et al, 2007).

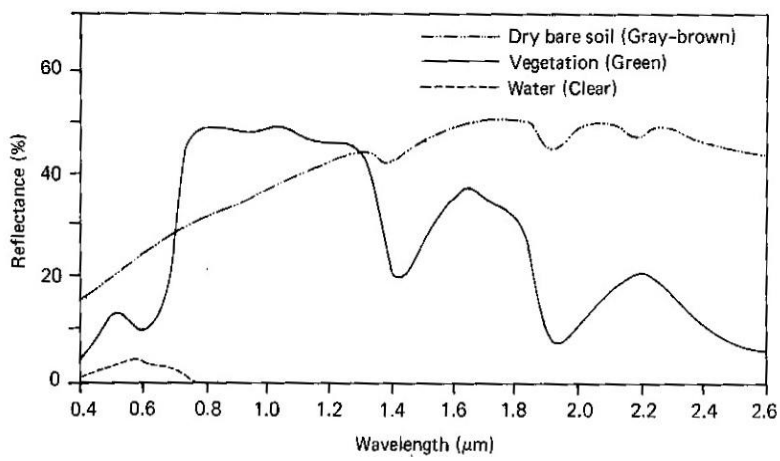

Figure 2.1 Typical spectral reflectance curves for soil, vegetation and water (Source; Lillesand and Kiefer, 1994)

One of the major applications of remote sensing technology is the change detection due to its repetitive coverage at short time intervals and consistent image quality (Singh, 1989). Change detection encompasses the quantification of temporal phenomena from multi-date imagery (Coppin et al, 2004). Change detection algorithms analyze multi-images of the same scene taken at different times to identify regions of change (Lunetta and Elvidge, 1999). The ability to detect regions of change in images is a powerful tool that can be used in a diverse range of applications including land use and land cover change analysis (Reis, 2008), detection of urbanization changes (Lacroix et al, 2006), assessment of deforestation (Torahi and Rai, 2011), and disaster management (e.g., monitoring of changes during flooding) (Sanyal and Lu, 2004). The basic principle of using remote sensing data for change detection is the changes in land cover result in changes in the radiances value which can be remotely sensed (Mas, 1999).

2.4 Integration of Remote Sensing and GIS Technologies

Ehlers (1990) stated that the capabilities of GIS to accept large volumes of spatial data from remote sensors, and to efficiently store, retrieve, manipulative, analyze, and display these data according to user-defined specifications can made remote sensing data to be utilized to the best. GIS improves the ability to extract information from remote sensing data, and remote sensing data can describe actual environmental conditions for updating suitable GIS databases (Miller and Rogan, 2007).

According to Wilkinson (1996), remote sensing and GIS technologies complement with each other in three major ways:

(i) remote sensing can be used as a tool to gather datasets for use in GIS

(ii) GIS datasets can be used as ancillary information to improve products derived from remote sensing, and

(iii) remote sensing and GIS data can be use together in environmental modeling and analysis.

Integration of remote sensing and GIS technologies provide efficient method for analysis of land cover issues and tools for land cover planning and modeling.

With an understanding of driving forces of land cover change in the past as well as managing the current situation and modeling the future with modern GIS tools, a person able to develop plans for various uses of natural resources and nature conservation (Gajbhiye and Sharma, 2012). A GIS, therefore plays a critical role in analysis remote sensing data owing to its comprehensive spatial database and powerful spatial analytical function (Gao, 2009).

2.5 Satellite Image Analysis

2.5.1 Pre-processing

The main objective of the satellite images pre-processing is to correct geometrically distorted and radiometrically degraded images to create a more reliable images representation (Gao, 2009). Image pre-processing is significant prior to actual change detection, in which its unique goals the establishment of a more direct linkage between the data and biophysical phenomena (Coppin et al, 2004). There have various types of pre-processing methods and no definitive list of "standard pre-processing steps" even though a certain pre-processing methods frequently used because it depends on the personal performance for some pre-processing decision on each project (Campbell, 2002).

2.5.1.1 Geometric Correction

The common methods for geometric correction involve image-to-map rectification and image-to-image registration. *Image rectification* is the process of transforming the image from one grid system into another grid system using a geometric transformation (ERDAS, 1999). While *image registration* is the process of overlaying two or more images of the same scene taken at different time, from different viewpoints or sensors and it geometrically aligns two images – the reference and sensed images (Zitová and Flusser, 2003). These methods is critical for correcting nonsystematic error especially image rectification (Lillesand and Kiefer, 1994). Image rectification and registration involve similar sets of procedures which are divided by three general steps; (1) locate the ground control points (GCPs); (2) compute and test a transformation; and (3) resampling the image onto a new grid system (ERDAS, 1999).

Root mean square error (RMSE) is the error term usually used to determine the accuracy of the transformation from one coordinate system to another. It is difference between the desired output coordinate for a GCP and the actual. RMSE is calculated with a distance equation as followed (ERDAS, 1999):

$$RMSE = \sqrt{(x_r - x_i)^2 + (y_r - y_i)^2} \quad (1)$$

Where,

x_i and y_i are the input source coordinates

x_r and y_r are the re-transformed coordinates

Congalton and Green (2009) recommend that the RMSE values below than 0.5 pixel threshold were considered acceptable for rectification and registration of remotely sensed data.

2.5.1.2 Image Enhancement

Image enhancement is basically improving the visual interpretability of an image and providing better input for other automated image processing methods

(Maini and Aggarwal, 2010). The principal objective is to create a more suitable image for a given task and specific observer by modifying its attributes (Verma and Gupta, 2013). The process attempts to optimize the complementary abilities of the human mind and the computer (ERDAS, 1999; Lillesand and Kiefer, 1994). According to Gao (2009), image enhancement serves as a preparatory step for subsequent process such as classification and visual interpretation.

2.5.1.2.1 Optimum Band Combination

The Optimum Index Factor (OIF) was developed by Chavez et al (1982) is given by

$$OIF = Max\left[\frac{\sum_{i=1}^{n}\sigma(i)}{\sum_{j=1}^{n}|r(j)}\right] \qquad (2)$$

Where,

$\sigma(i)$ is the standard deviation of k band

$r(j)$ is the correlation matrix value

The technique is a statistical approach usually applied on satellite image in order to rank all possible 3-band combinations (Ren and Abdelsalam, 2001). It is based on total variance within bands and correlation coefficient between various bands (Qaid and Basavarajappa, 2008; Jensen, 1996). 3-band combinations with high total variance within bands and low correlation coefficient between bands will have high OIF. The highest OIF indicate that the 3-band combination contains the most information with the least amount of duplication (Ibrar Ul, 2012; Qaid and Basavarajappa, 2008).

2.5.1.2.2 Pan-sharpening

"Pan-sharpening" is commonly used from the term "Panchromatic sharpening". It is a type of data fusion that refers to the process of merging higher spatial resolution panchromatic with lower resolution multispectral imagery to create a single high-resolution color image (Padwick et al, 2010). The Intensity-Hue-Saturation (IHS) merge, which has been the most popular algorithm used in pan-sharpening (Chavez et al, 1991; Vrabel, 1996; Pohl and Genderen, 1998), comprised of the following three steps: (1) transform the MS bands from RGB color space into IHS color space; (2) replace the intensity component with the panchromatic image; and (3) perform and inverse IHS transform to convert back the data into RGB color space (Vrabel, 1996).

The mathematical context for the transformation from RGB to IHS and inverse transformation from IHS to RGB is expressed by equation (3) (a-c) and (4) respectively:

(a) $$\begin{bmatrix} I \\ v1 \\ v2 \end{bmatrix} = \begin{bmatrix} 1/\sqrt{3} & 1/\sqrt{3} & 1/\sqrt{3} \\ 1/\sqrt{6} & 1/\sqrt{6} & -2/\sqrt{6} \\ 1/\sqrt{2} & -1/\sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{3}$$

(b) $$H = tan^{-1} \begin{bmatrix} v2 \\ v1 \end{bmatrix}$$

(c) $$S = \sqrt{v1^1 + v2^2}$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1/\sqrt{3} & 1/\sqrt{6} & 1/\sqrt{2} \\ 1/\sqrt{3} & 1/\sqrt{6} & -1/\sqrt{2} \\ 1/\sqrt{3} & -2/\sqrt{6} & 0 \end{bmatrix} \begin{bmatrix} I \\ v1 \\ v2 \end{bmatrix} \tag{4}$$

I relates to the intensity, while *'v1'* and '*v2*' represent intermediate variables which are needed in the transformation. *H* and *S* stand for Hue and Saturation respectively

(Pohl and Genderen, 1998). The images with better spatial resolution may be said to show the finer detail than image with lower spatial resolution at the same scale and of the same area (Gibson, 2000)

2.5.1.2.3 Contrast Stretching

Many natural surface features have low range of reflectance value in any bands and leads to low contrast of image (Gibson and Power, 2000). Such problems can be solved by applying the contrast stretching method. The idea behind contrast stretching is to expand the narrow range of gray levels in the image being processed and produce an output image which highlights the contrast between features of interest to image analyst (Al-Amri, 2011; Lillesand and Kiefer, 1994). There are two main types of contrast stretching techniques such as linear and nonlinear stretch which can improve the visual interpretation capabilities (Hwa and Kyu, 2012; Jensen, 1996). Mathematically, contrast stretching is expressed as (Gao, 2009)

$$DN_{out} = f(DN_{in}) \quad (5)$$

Where,

DN_{out} = output DN in the contrast-stretched image

DN_{in} = DN of the same pixel in the original image

f = transformation function through which contrast is manipulated (linear or nonlinear)

Ordinarily, a contrast stretching is applied for display only, so that the data file values are unchanged (ERDAS, 1999).

2.5.1.2.4 NDVI

NDVI was introduced by late Rouse et al. (1973), which is a most widely index used as an indicator for vegetation density (Ünsalan and Boyer, 2011) and useful in enhancing the visibility of healthy vegetation in satellite image (Gibson, 2000). The formula is based on the fact that chlorophyll pigment in green leaf structures absorbs RED whereas mesophyll cells reflected back NIR (Pettoreli et al, 2005). The mathematical equation of NDVI is as follows;

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (6)$$

Where,

NIR = the spectral reflectance measurement acquired in the near-infrared region (0.78µm – 0.89µm)

RED = the spectral reflectance measurement acquired in the red region (0.61µm – 0.68µm)

Theoretically, NDVI values range from -1 to +1. The higher values of NDVI indicate for the green vegetation and low values for other common surface materials (Karaburun, 2010). NDVI helps compensate for changing illumination conditions, surface slope, aspect, and other extraneous factors (Lillesand and Kiefer., 1994).

2.5.2 Image Classification

Unsupervised and supervised are two primary techniques of image classification, especially for land cover classification. The unsupervised classification techniques separate image pixels into natural groupings based upon similar spectral characteristics and the analyst subsequently turn those groupings to informational classes (Enderle and Weih Jr, 2005). There are varieties of clustering algorithm can be used in unsupervised classification including Iterative Self-Organizing Data Analysis (ISODATA) clustering. The ISODATA clustering method uses spectral distance as in the sequential method, but iteratively classifies the pixels, redefines the criteria for each class, and classifies again, so that the spectral distance patterns in the data gradually emerge (ERDAS, 1999).

In contrast, supervised classification techniques involves in clustering image pixels in a data set into classes corresponding to user-defined training class (Wang and Tenhunen, 2004). The technique requires on individual pattern recognition skills and a prior knowledge of the image to assist the system determine the signature for image classification (ERDAS, 1999). According to Richards and Jia (2006), Maximum Likelihood Classifier (MLC) is the most common supervised classification algorithm used with remote sensing data. The MLC comparison to the other classifiers such as Parallelpiped and Minimum Distance produces a more reliable result owing to its complexity and using more statistical parameters of the training classes (Gao, 2009). MLC used the mean vector and the covariance matrix of the training classes, to estimate a statistical probability of pixels belonged to a specific class with an assumption that the histogram of each class normally distributed (Lillesand and Kiefer, 1994).

There are several advantages and disadvantages of using unsupervised and supervised approach to classification according to Enderle and Weih Jr (2005). In unsupervised classification, they stated that the main advantages of using this approach such as the knowledge of the study area is not necessary, human error is minimized because only a few decisions involving analysts and unsupervised classification recognize the unique classes in the data unlike supervised classification tend to overlooked it. On the other hand, the disadvantages are the natural groupings identified through classification process are spectrally homogeneous which does not necessarily fit with the desired informational classes and the analysts have restricted control over the classes selected by the classification process.

Enderle and Weih Jr (2005) also stated that the advantages of the supervised classification technique include the following: the analyst has full control of the informational class to be assigned in the final classification, the resulting classification are bound to particular areas on the image of known identity, the selecting training class process solve the problem of matching spectral classes to informational classes and errors in classification process can be detected by comparing the final classification with the training class (Campbell, 2002). There are also disadvantages to the use of this approach. First, the extensive knowledge of study area is required and time consuming. Second, the classification results tend to overlap and ambiguity because of spectral properties is not the primary characteristics used in identifying training areas. Third, the analyst is imposing a classification structure upon the data. Finally, unique classes present in the image may be overlooked during the selection of training classes (Enderle and Weih Jr, 2005).

Many studies have shown the combination of unsupervised and supervised classification in land cover classification can produced better results than its individual classification (Pradhan et al, 2010; Krishna, 2009; Enderle and Weih Jr, 2005). This combination approach also called as hybrid classification taking the advantages of both classifications to improve the results (Pradhan et al, 2010). Hybrid classification involves the use of unsupervised classification in generating training class followed by classifying the pixels using supervised classification (Richards and Jia, 2006). According to Lillesand and Kiefer (1994), hybrid classifiers are particularly valuable in analyses in which there is presence of complex variability in the spectral response pattern for individual cover types, for example detecting land cover types in mountainous areas which involve of variation within cover type per se (species) and different site conditions (soils, slope, aspect). Hybrid techniques in generating LULC map derived from remote sensing data produced the classification accuracy within the range of 73% to 93% which frequently reported by numerous researchers (Rozenstein and Karnieli, 2011; Pradhan et al, 2010; Kamusoko and Aniya, 2009;.Omo-Irabor and Odeyumi, 2007; Enderle and Weih Jr, 2005).

2.5.3 Post-Classification Processing

Pixel based classification often produce classified images with some so-called “salt–pepper” appearance due to the inherent spectral variability encountered by a classifier (Lillesand and Kiefer, 1994), i.e., the presence of scattered pixels, classified as rangeland in an almost homogenous area that categorized as forest class. This type of error can be reduced by applying majority filtering onto an output images. In majority filtering, the minority within the operating window is integrated into their dominant surrounding covers (Gao, 2009). As show on Figure 2.2, since the central pixel has a value of 3 (Figure 2.2a) and the majority of pixels in the window have a value of 4, its value is changed to 4 in the output image (Figure 2.2b)