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High Spatial Resolution Land Cover Mapping Using Remotely Sensed Image

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Abstract

Land cover classification from remotely sensed data is an important topic in remote sensing applications. This paper present an economical analysis of land covers in Mebok Estuary, Penang, Malaysia. This study investigated the potential of using digital camera for land cover mapping Mebok Estuary, Penang, Malaysia. Airborne digital imagery has proved to be an effective tool for land cover studies. A Kodak camera, model DC290, was used to capture images from an elevation of 2438.4 meter on board Cessna 172Q. The use of digital camera as a sensor to capture digital images is cheaper and economical compared to the use of other airborne sensor. This technique overcomes the problem of the difficulty in obtaining cloud-free scenes in the Equatorial region from a satellite platform. Supervised classification techniques were used in the classification analysis. Supervised classification technique (Parallelepiped with Maximum Likelihood as tie breaker classifier, PML, Maximum Likelihood, ML, Minimum Distance-to-Mean, MDM, and Parallelepiped, P) was applied to the digital camera spectral bands (red, green and blue) to extract the thematic information from the acquired scenes. The best supervised classifier was chosen based on the highest overall accuracy and Kappa statistic. The accuracy of the classified images was validated using a reference data set. The study revealed that the Parallelepiped with Maximum Likelihood as tie breaker classifier produced superior result and achieved a high degree of accuracy. The classified land cover map was geometrically corrected to provide a geocode map. The results produced by this study indicated that land cover features could be clearly identified and classified into a land cover map. This study suggested that the land cover types of Mebok Estuary, Penang, Malaysia can be accurately mapped.

Keywords: Classification, Land Cover, Airborne, Supervised classification, Kodak

1. Introduction

Land cover is a fundamental variable that impacts on and links many parts of the human and physical environments (Foody, 2002). This is important for it provides useful information for planning the area. Remote sensing technology is able to prepare the latest data with multiple scales and can be used in many purposes. Land cover mapping at coarse spatial resolution provides key environmental information needed for scientific analyses, resource management and policy development at regional, continental and global levels (Latifovic, et al., 2004). The increasing availability of remote-sensing images, acquired periodically by satellite sensors on the same geographical area, makes it extremely interesting to develop the monitoring systems capable of automatically producing and regularly updating land-cover maps of the considered site (Bruzzone, et al., 2002).

A basic problem for any country or region in economic planning, environmental studies, or resource management is accurate, current information. The need for basic surface characteristic information, such as land use and land cover, is critical to both scientific analysis and decision-making activities. Without accurate information, scientists cannot complete valid studies and decision-makers often fail to make decisions or make incorrect decisions (Haack and Bechdol, 2000). The availability of remote sensing data applicable for global, regional and local environment monitoring has greatly increased over recent years (Ehlers, et al., 2003). Land cover is a fundamental parameter describing the Earth's surface. With sufficient calibration, a land cover map can be used to identify spatial patterns of physical quantities such as carbon storage or vegetation cover as well as more abstract phenomena such as land use. Accurate information on land cover is required for both scientific research (eg, climate change modeling, flood prediction) and management (eg, city planning, disaster mitigation) [Tatem, et al., 2001].

The sensor used in this study was a normal digital camera model Kodak DC290, and a light aircraft was used as a platform to capture the digital images. The cost of the present sensor is very much cheaper than available airborne sensors. Besides, this study is also good for collecting data in planning and management. Digital cameras have been used in many researchers in remote sensing application (Ellis and Dodd 2001, Nakada and Chikatsu 2003, Levesque and King 1999, Heier and Hinz, 1999, White, et al. 2000, Mohammed et al. 2007, Yamamoto and Takagi 2007, Fugate and Aaron 2008). A Canon Camera EOS 1D Mark II 8 MPixel digital camera was used by Reinartz, et al., (2006) for traffic monitoring. Dean, et al, (2000) and Mason, et al., (1997) also used a Kodak DCS460c in their study of vegetation analysis and small area mapping respectively. A Nikon Coolpix 885, CP885 was used by Goddijn and White, (2006) for water quality measurements in Galway Bay.

The objective of this study is to investigate the potentiality of using digital camera imagery for land cover mapping. In this study, digital images were acquired from a digital camera for land cover mapping. Supervised classification of remote-sensing images has been widely used as a powerful means to extract various kinds of information concerning earth environment. Supervised classification methods were applied to the digital images. Maximum Likelihood classifier was found to produce the best accuracy in this study. Many researchers choose the Maximum Likelihood method in their studies [Saura and Miguel-Ayanz, (2002), Pal and Mohanty, (2002), Donoghue and Mironnet, (2002), Thiemann and Kaufmann, (2000) and Guerschman, et al., (2003)]. The monitoring task can be accomplished by supervised classification techniques, which have been proven to be effective categorization tools (Bruzzone, et al., 2002). The accuracy assessment of the classified images also has been done in this study. The traditional method of collecting data for planning is surveying samples at field. Remote sensing technique is a useful method for classifying the image. With process data available, a quick decision about the area can made.

2. Study area and Data Acquisition

The study area was the Merbok river estuary, located within latitudes and 5^o 39' N to 5^o 41' N and longitudes 100^o 20' E to 100^o 24' E, respectively (Figure 1). The study area was located at the north of Peninsular Malaysia. The whole length of Merbok River, being tidally influenced, is mangroved-fringed where saltwater intrusion can be experienced until the upstream end of the river. The estuary width ranges from about 2000 m at the estuary mouth to about 15 meter towards the upper reaches with depths varying from 15 meter to 3 meter (except for a few 20 meter deep holes where tributaries join the Merbok). The catchment area of Merbok Estuary measures 500,000,000 m^2. The dry season is in December, January and May with rainfall maxima in October-November and April. The mean annual discharge is estimated to be 20 m^3s^{-1}. Freshwater discharge into the mangrove estuary is not from a single river but rather from numerous small streams that feed into a number of estuarine tributaries. So even if the main river is gauged, this discharge does not represent the total freshwater input to the estuary. A digital camera, Kodak DC 290 (Figure 2) was used to capture digital images from a light aircraft, Cessna 172Q, at 2438.4 meter of altitude. The digital images were captured during the flight between 9 a.m. to 11 p.m. on 9 March 2002 from a light aircraft flying at an altitude of 2438.4 meter on 9 March 2002.

3. Remote Sensor

Kodak is without question one of the dominant companies in the field of photography. While the bulk of their enormous business is built upon conventional film-based photography, they clearly recognize that the future lies with digital (The Imaging Resource, 1999). In this study, red–green–blue (RGB) digital outputs from a digital camera, a Kodak DC 290, were used to estimate water quality parameters. The front of the Kodak DC290 holds the 3x optical zoom lens, autofocus sensor, flash, self-timer light, optical viewfinder, light and flash sensors and a nice, thick hand grip (Figure 2). The Kodak DC 290 is a 2.3-mega pixels digital camera and storage digital images in JPEG and uncompressed TIFF file formats. The technical specification for the Kodak DC 290 can be obtained from KODAK DC290 Zoom Digital Camera User's Guide Camera Specifications - http://wwwde.kodak.com/global/en/service/digCam/dc290/ownerManual/ch14.shtml#76207. Its sensor is capable of acquiring data in multispectral mode (3-bands: red, green and blue). According to Ahmad, et al., (2002), Kodak DC 290 is categorized as a high-resolution digital camera.

The technical specification for the Kodak DC 290 is shown in Table 1. Its sensor is capable of acquiring data in multispectral mode (3-bands: red, green and blue). There are many types of digital cameras available in the market. Any person could possess the camera either for personal use, for producing reports or for research and other purposes. The use of digital camera is preferable since digital images could be stored on-board and easy to operate. Digital cameras are manufactured with different sensor sizes and resolutions. Sensor size is defined by width and height of sensor array in millimeter or inches. On the other hand, sensor resolution is defined by number of horizontal pixel multiplied by number of vertical pixel. A digital camera could be categorized as (1) low resolution if the number of pixels is less than 500, 000; (2) medium resolution between 500, 000 to 1.5 million and (3) high resolution if number of pixel is beyond 1.5 million. The cost of the digital camera depends on the resolution. Normally, digital camera of low resolution is much cheaper compared to digital camera of medium and high resolution (Ahmad, et al., 2002). According to Ahmad, et al., (2002), Kodak DC 290 is categorized as a high-resolution digital camera. Recently, the number of pixels of amateur digital cameras is amazingly increased by modern semiconductor and digital technology. Nevertheless, the highest pixel of amateur digital camera was 0.8 Mega pixels in 1996 and the highest pixel was 5.24 Mega pixels in 2001. It is expected that high-resolution amateur digital camera will become a useful tool in various photogrammetric fields (Nakada and Chikatsu, 2003).

4. Methodology

The aim of the classification analysis is to categorize all of the pixels in the digital camera imagery into land cover classes. Figure 2 illustrates the classification analysis flow chart. Basically, the process can be divided into three simple steps, the pre-processing, data classification and output. In the pre-processing, the classes were established by using polygons for training sites. They are delineated by spectrally homogeneous sub areas, which have, class name given. Accuracy assessment was done in this study to compute the probability of error for the classified map. Many methods of accuracy assessment have been discussed in remote sensing literatures. Three measures of accuracy were tested in this study, namely overall accuracy, error matrix and Kappa coefficient. The confusion matrix is currently at the core of the accuracy assessment literature (Foody, 2002). The most widely promoted and used accuracy measure, however, may be derived from a confusion or error matrix. The Kappa statistic is a statistical method of assessing accuracy that takes into account the chance of random agreement. This statistic has been used by many researchers in their studies [Selamat, et al., (2002), Dymond and Johnson, (2002)].

5. Data Analysis and Results

The size of the airborne colour digital image of the Merbok River estuary is 1200 pixels by 1792 lines (Figure 3). All image-processing analysis was carried out using PCI Geomatica version 10.1.3 software at the School of Physics, Universiti Sains Malaysia (USM), Malaysia. Three supervised classification methods were performed to the digital images (Maximum Likelihood, Minimum Distance-to-Mean, and Parallelepiped). The digital image was classified into four classes using all the three bands. Training sites were needed for supervised classification. Selection of training areas in this study was based on the colour image. A total of 12 sample-training areas were studied in this analysis. A total of 100 samples were chosen randomly for the accuracy assessment.

The digital image was classified into 6 classes, namely forest, water, land, urban, cloud and cloud Shadow. Kappa coefficient and overall accuracy results of the three measures of accuracy are shown in Table 2. The overall accuracy is expressed as a percentage of the test-pixels successfully assigned to the correct classes. Producer's accuracy indicates how well training set pixels were classified, user accuracy indicates the probability that a classified pixel actually represents that category in reality and overall accuracy is the total number of correctly classified pixels divided by the total number of reference pixels (Rogan, et al., 2002).

Parallelepiped with Maximum Likelihood as tie breaker classifier produced the highest degree of accuracy with overall accuracy of 89.5%, Maximum Likelihood gave overall accuracy of 88.0%, Minimum Distance-to-Mean gave overall classification accuracy of 75.5%, and Parallelepiped resulted in the overall classification accuracy of 26.5%. Table 2 shows the results of overall classification accuracy and Kappa coefficient using supervised classification techniques of PML, ML, MDM and P classifier. The classified images using supervised classification techniques of PML, ML, MDM and P classifier are shown in Figure 4.

6. Conclusion

From the four classified maps, Parallelepiped with Maximum Likelihood as tie breaker gives a good result for land cover mapping. The digital camera imagery can be used to provide useful data for planning and management. The digital images used in this study were captured by a Kodak DC290 digital camera from a low-altitude flying aircraft that is cheap and economical compared with using a scanner/sensor placed on either airborne or satellite. Besides, this technique can also overcome the problem of difficulty in obtaining cloud-free images from satellites in equatorial region. This study provide an alternative to obtain the remotely data for land cover mapping.

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Table 1. The technical specification for the digital camera model Kodak DC 290

Pixel Resolution	CCD	1901 x 1212=2.3 millions of pixels (total number of pixels)
	Ultra	2240 x 1500=3,360,000
	High	1792 x 1200=2,150,400
	Medium	1440 x 960=1,382,400
	Standard	720 x 480=345,600
Color		24-bit, millions of colors
Picture File Format		Exif version 2.1 (JPEG base) or TIFF
Picture Storage		External memory only: ATA compatible Compact Flash card
Viewfinder		Real image
ASA/ISO Sensitivity		100
Flash Range	Wide	1.6 ft to 13.1 ft (0.5 to 4.0 m)
	Telephoto	1.6 ft to 8.2 ft (0.5 to 2.5 m)
Lens	Type	Optical quality glass
	Maximum Aperture	Wide: F/3 Telephoto: F/4.7
	Zoom	6X: 3X Optical zoom 2X Digital zoom
	Focal Length	38.4 to 115.2 mm (equivalent to 35 mm camera) 8 to 24 mm (actual)
	Auto Focus	Wide/Telephoto: 1.0 ft (0.3 m) to infinity
	Manual Focus	Wide/Telephoto: 1.6 ft (0.5 m) to infinity
Power	Batteries	AA size 1.5-volt alkaline, or AA size 1.2-volt Ni-MH rechargeable
	DC Input	AC Adapter for KODAK DC200 Series Digital Cameras
Tripod Socket		.25 in. (.006 m) threaded
Video Out		NTSC or PAL
Dimensions	Width	4.6 in. (118 mm)
	Length	2.5 in. (63 mm)
	Height	4.2 in. (106 mm)
Weight		1.2 lbs (525 g) without batteries
Operating Temperature		32 to 104° F (0 to 40° C)

(Source: KODAK DC290 Zoom Digital Camera User's Guide Camera Specifications)

Table 2. The overall classification accuracy and Kappa coefficient.

Classification method	Overall classification accuracy (%)	Kappa coefficient
Maximum Likelihood	88.00	0.799
Minimum Distance-to-Mean	75.50	0.609
Parallelepiped with Maximum Likelihood as tie breaker	89.50	0.824
Parallelepiped	26.50	0.198

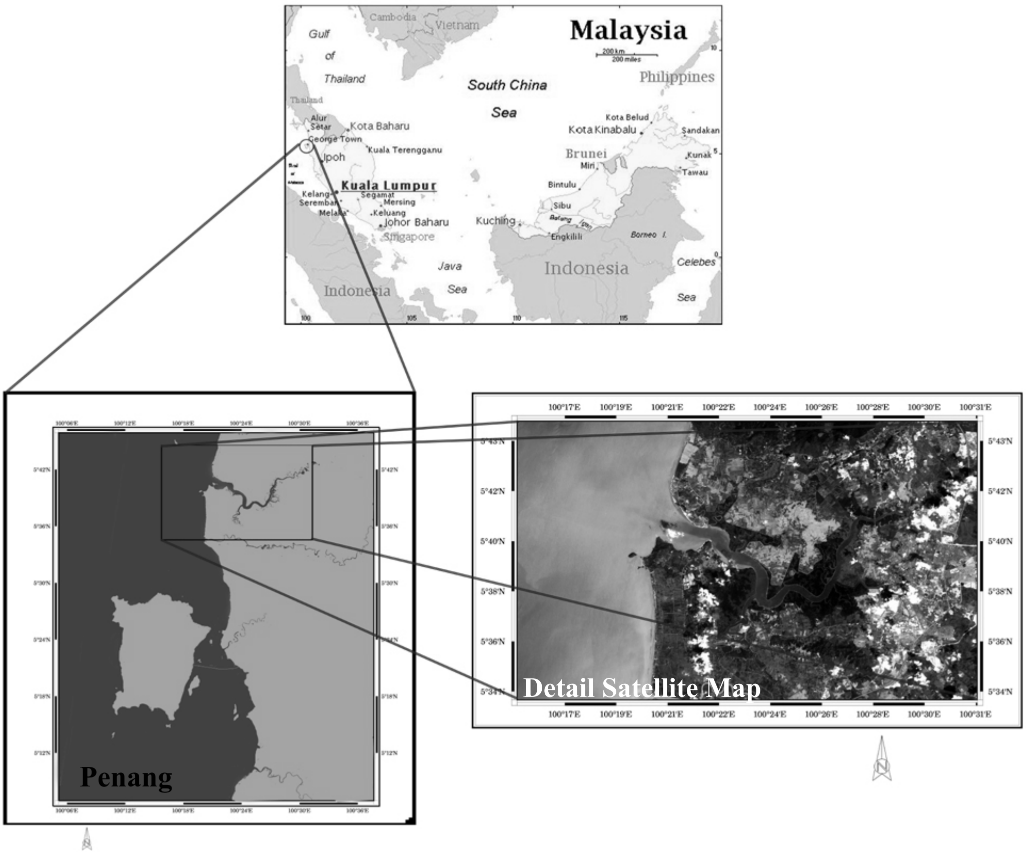


Figure 1. The study area

Figure 2. Digital Camera- Kodak DC290
(Source: Stargate Systems, INC: Digital Cameras - Kodak, 1999)

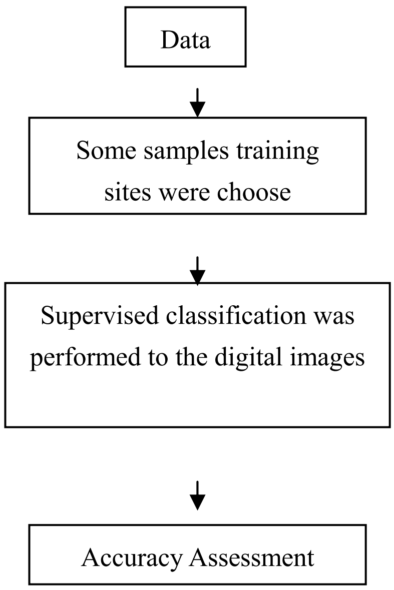
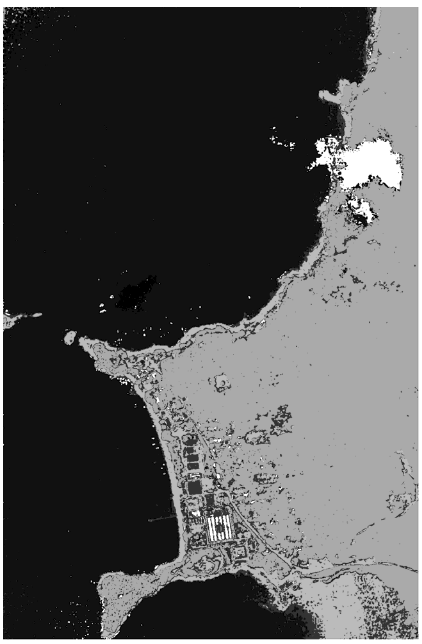
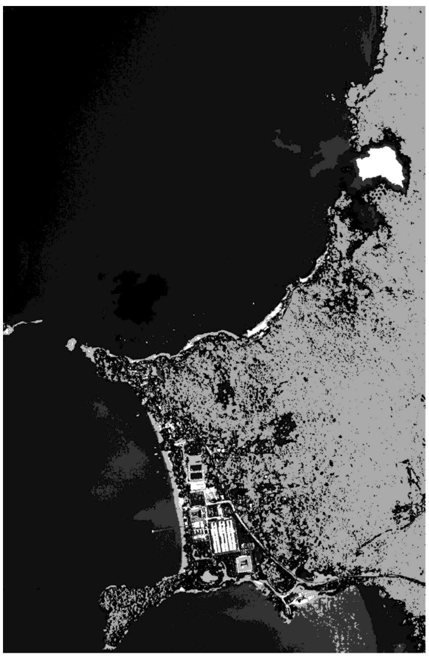


Figure 3. Flow chart for data processing of the images

Figure 4. The image used in the classification.

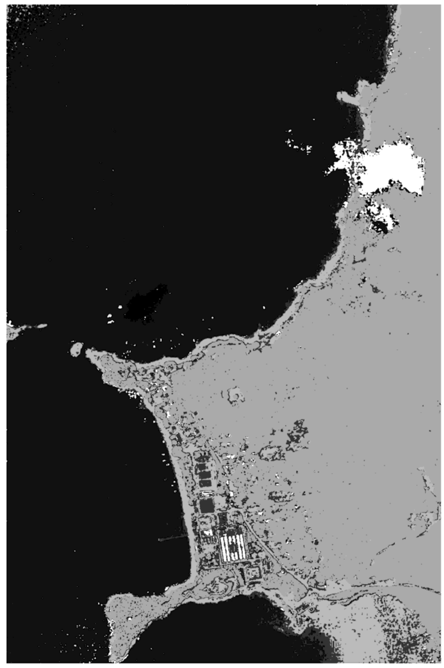


(a) Maximum Likelihood



(b) Minimum Distance-to-Mean

(c) Parallelepiped



(d) Parallelepiped with Maximum Likelihood as tie breaker

Figure 5. The classified images using supervised technique (a) Minimum Likelihood, (b) Minimum Distance-to-Mean, (c) Parallelepiped and (d) Parallelepiped with Maximum Likelihood as tie breaker (Forest = Green, Water = Blue, Land = Orange, Urban = Red, Cloud = White and Cloud Shadow = Black).