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MONITORING OF AGRICULTURAL LAND ABANDONMENT USING REMOTE SENSING TECHNOLOGY

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By

NORYUSDIANA MOHAMAD YUSOFF

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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DEDICATION

This thesis is dedicated to

My husband
Zuhairi Abdullah

My supervisor
Dr. Farrah Melissa Muharam

My parents
Muhammad Yusoff Musa and Norizan Md Noor

My parents-in-law
Abdullah bin Chik and Saripah Abd. Ghani

My kids
Nur Tasnim Amani Zuhairi
Adam Zafri Zuhairi
Nur Jannah Arissa Zuhairi

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

MONITORING OF AGRICULTURAL LAND ABANDONMENT USING REMOTE SENSING TECHNOLOGY

By

NORYUSDIANA BINTI MOHAMAD YUSOFF

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Chair: Farrah Melissa Muharam, PhD
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Abandonment of agricultural land is a global issue, it is a waste of resources and brings negative impacts on local economy. It is also a key factor in certain environmental problems, such as soil erosion and increasing carbon sequestration. In order to address such problems related to land abandonment, their spatial distribution must first be precisely identified. This study utilized the multi-temporal of Landsat, ALOS PALSAR-1 and 2, and SPOT-6 images together with crop phenology information, to identify abandoned paddy, rubber and oil palm areas. With the advancement of object-oriented classification, the identification was done semi-automatically by developing rules set. The results indicated that time series images were highly beneficial in identifying unique phenology of abandoned and non-abandoned paddy area whereas, a minimum of three time-series images during planting seasons were required. In identification of abandoned rubber area, the use of image acquired during defoliation (leaf-off) phase was preferable to avoid misclassification. However, in identification of abandoned oil palm, homogeneity measures obtained from high spatial resolution satellite image was more important than high spectral resolution satellite image. The study demonstrated the advantages of using multi-temporal Landsat imagery in identifying abandoned paddy and rubber areas wherein accuracies of 93.33% ± 14% and 83.33% ± 1%, respectively, were achieved. For multi-temporal of ALOS PALSAR-1 and 2, accuracies obtained for these abandoned lands of paddy, rubber and oil palm were 93.33% ± 0.06%, 78% ± 2.32%, and 63.33% ± 1.88%, respectively. For classifying abandoned oil palm, SPOT-6 showed an accuracy of 92% ± 1%. As a conclusion, remote sensing technology have shown the potential to monitor agricultural land abandonment and is greatly useful especially when large and inaccessible areas are involved. This study confirmed that the understanding of crop phenology in relation to image date selection is essential to obtain high accuracy for classifying abandoned and non-abandoned agricultural crops. Generally, this study had successfully developed a semi-automated technique of land abandonment identification using multi-resolution and multi-temporal satellite images. With the robustness of the techniques developed based on the image rules set and crop phenology, the monitoring of agricultural land abandonment can be expanded nationwide by adjusting the rules set.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMANTAUAN TANAH PERTANIAN TERBIAR MENGGUNAKAN TEKNOLOGI REMOTE SENSING

Oleh

NORYUSDIANA BINTI MOHAMAD YUSOFF

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Tanah pertanian terbiar adalah salah satu isu global berikutan kesan negatif terhadap aktiviti sosial dan ekonomi sesebuah negara. Ia juga merupakan punca kepada masalah alam sekitar seperti tanah runtuh dan meningkatkan proses penyerapan karbon. Bagi menangani masalah ini, faktor utama yang perlu dikenalpasti adalah lokasi yang tepat di mana tanah tersebut ditinggalkan tanpa sebarang aktiviti. Kajian ini menggunapakai imej satelit Landsat, ALOS PALSAR-1 dan 2 pelbagai temporal, dan SPOT-6, beserta maklumat fenologi tanaman untuk mengenalpasti kawasan padi, getah dan kelapa sawit terbiar. Sejajar dengan perkembangan kaedah pengkelasan imej berasaskan objek, pengkelasan kini dapat dijalankan secara separa automatik dengan pembangunan *rules set*. Kajian mendapati imej pelbagai temporal amat penting bagi mengenalpasti keunikan fenologi kawasan tanah terbiar padi dan tidak terbiar padi, di mana sekurang-kurangnya tiga siri imej diperlukan semasa aktiviti tanaman dijalankan. Bagi mengenalpasti tanah terbiar getah, penggunaan imej semasa fasa daun luruh amat membantu bagi mengelakkan kesilapan semasa proses pengkelasan. Walau bagaimanapun, bagi tujuan pengenalpastian tanah terbiar kelapa sawit, resolusi spatial sesuatu imej adalah lebih penting berbanding resolusi spektral. Hasil akhir menunjukkan penggunaan imej Landsat pelbagai temporal berupaya memetakan kawasan tanah terbiar padi dan getah dengan ketepatan sebanyak 93.33% ± 14% dan 83.33% ± 1% masing-masing. Penggunaan imej pelbagai temporal ALOS PALSAR-1 dan 2 pula berupaya memetakan tanah terbiar padi, getah dan kelapa sawit dengan ketepatan sebanyak 93.33% ± 0.06%, 78% ± 2.32%, dan 63.33% ± 1.88% masing-masing. Bagi menambahbaik ketepatan tanah terbiar sawit, imej satelit SPOT-6 pula digunapakai dan memperolehi ketepatan sebanyak 92% ± 1%. Sebagai kesimpulannya, teknologi remote sensing berpotensi untuk digunapakai bagi pemantauan kawasan tanah pertanian terbiar terutamanya sekiranya melibatkan kawasan yang luas dan sukar diakses. Selain itu, kajian ini juga menunjukkan perkaitan antara fenologi tumbuhan dan pemilihan imej satelit bagi memperolehi hasil pengkelasan tanah pertanian terbiar yang berketepatan tinggi. Secara keseluruhannya, hasil akhir kajian ini telah membangunkan satu teknik separa automatik bagi pemantauan tanah terbiar menggunakan imej satelit pelbagai temporal dan resolusi. Hasil ini dijangka dapat diperluaskan penggunaannya dengan teknik *robust* yang dibangunkan menggunakan *rules set,* dengan mengubahsuai nilai *threshold*.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Declaration by Graduate Student

I hereby confirm that:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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Member of
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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

In general, land abandonment refers to the land which is left idle for a certain time period and constitutes heterogeneous area (Alcantara et al., 2013; Gellrich, Baur, Koch, & Zimmermann, 2007; Soukup, Brodsky, & Vobora, 2009). Malaysian Department of Agriculture (2014) states that agricultural lands are considered abandoned when they are left uncultivated for three consecutive years or more, and the area has a minimum coverage of at least 0.4 ha. Numerous definition of abandoned land identified by several organizations and researchers as detail out in
Table 2.1.

Land abandonment is a worldwide issue and has been a long-time focus in Bulgaria (Milenov et al., 2014), Russia (Prishchepov, Müller, Dubinin, Baumann, & Radeloff, 2013), United States (Munroe, van Berkel, Verburg, & Olson, 2013), China (Zhang, Dang, Tan, Wang, & Zhang, 2010), Latvia (Colofon, 2004) and Malaysia as well (Buang, 2001; Othman, 1992). In some countries, more than 20% of the farmland is currently abandoned (Colofon, 2004). In Malaysia, idle agricultural land has become an issue since 1980s (Buang, 2001) due to socio-economic and environmental related problems. With the concern on global food demand, abandonment of agricultural lands could lead to the waste of fertile land for food production (Alcantara et al., 2013) especially in the Malaysian rice sector (Othman, 1992). On the other hand, land abandonment also negatively affects local economy, for instance, abandonment of plantation crops such as oil palm and rubber can threaten Malaysian economy since they contribute USD 10 billion and USD 1.6 billion to the country's gross domestic product (GDP), respectively. In terms of environment, Koulouri & Giourga (2007) found that when slope gradient is steep i.e. more than 25°, soil erosion increases significantly after abandonment due to changes in vegetation cover. Land abandonment has also been justified as a tool to increase carbon sequestration and biodiversity loss (Alcantara et al., 2013; Uri, Lõhmus, Kund, & Tullus, 2008).

Identifying land abandonment via the conventional method that is ground sampling is tedious especially when it involves large, scattered (Ponnusamy, 2013), and widespread areas (Alcantara et al., 2013). Besides, in the conventional identification process, land lot numbers, land owner, and crop suitability study are necessary (Department of Agriculture, 2014); hence, to detect and identify them from ground can pose a huge challenge in terms of cost, time, and labor. On the other hand, advanced technologies, such as remote sensing, using either low resolution image such as MODIS (Alcantara et al., 2013), medium resolution image such as Landsat (Prishchepov, Radeloff, Dubinin, & Alcantara, 2012) or high resolution image such as orthophoto (Larsson & Nilsson, 2005) has been explored for identification of abandoned land. Besides optical images, the potential of radar image in identifying abandoned land has also been explored (Darmawan, Takeuchi, Muharam, & Razak, 2015). Nowadays, by using an object-oriented classification technique, complemented with remote sensing images, monitoring of abandoned lands could produce fast result since it could be done automatically (Milenov et al., 2014).

In agriculture related remote sensing studies, understanding crop phenology is essential (Atkinson, Jeganathan, Dash, & Atzberger, 2012), especially for seasonal crops such as paddy and rubber. Crop phenology highlights the importance of utilizing multi-temporal images (Dong et al., 2015; Doug R. Oetter, 2000), in order to track reflectance changes during the cropland cycle (Prishchepov et al., 2012). For paddy, for example, the unique phonological characteristic are shown during flooding and transplanting phases (Dong et al., 2015), while as for rubber, the unique phenological characteristics are reflected during foliation and defoliation stages (Dong et al., 2013). However, for perennial crop such as oil palm, a single-date image might be sufficient due to the absence of seasonal effects in the oil palm leaves (Cracknell, Kanniah, Tan, & Wang, 2013).

1.2 Problem Statements

Statistic have shown that a total area of 119,273 ha, or 2%, of Peninsular Malaysia's arable soil was declared abandoned, as shown in Table 1.1 (Department of Agriculture, 2014). However, this statistic kept changing due to additions of newly abandoned lands or development of previously abandoned lands (Department of Agriculture, 2014). As previously highlighted, abandoned lands are commonly scattered (Ponnusamy, 2013), and widespread (Alcantara et al., 2013); hence, ground sampling is not an efficient approach to identify their spatial distribution.

Table 1.1: Summary of idle land by states (Department of Agriculture, 2014)

No.	State	Lot No.	Area (ha)
1.	Perlis	55	54.51
2.	Kedah	3,065	5,518.98
3.	Pulau Pinang	267	419.30
4.	Perak	5,214	14,506.92
5.	Selangor	3,030	9,395.05
6.	Negeri Sembilan	6,404	10,309.14
7.	Melaka	2,568	3,629.97
8.	Johor	8,070	17,854.93
9.	Pahang	19,510	34,293.27
10.	Terengganu	11,604	12,309.22
11.	Kelantan	8,663	8,907.04
12.	WP Labuan	1,284	2,075.04
	Total	**69,734**	**119,273.38**

These characteristics of abandoned lands signifies the use of advanced space technology in identifying and mapping them, in which remote sensing can play a vital role. The immediate advantages of using remote sensing is the widespread coverage of study areas in a short time frame, and suitable for detecting remote abandoned lands that are inaccessible by ground surveyors. In general, reliable monitoring of abandoned agricultural lands using remote sensing data is parallel to the aspiration of the government to decrease the country's reliance on imported foods and thus net values on food import. For a long term benefit, this monitoring could be an essential component of a food security programme. In addition, rehabilitation of abandoned land is essential in order to avoid land expansion for food crop production and plantation industry, in the limelight of land scarcity.

1.3 Objective of the Study

The overarching goal of this study is to identify and detect the abandoned agricultural land using remote sensing technology. The following are the study's specific objectives:

1.3.1 To develop crop phenology and classification methodology in detecting main agricultural crop abandonment using multi-temporal Landsat imagery;

1.3.2 To develop crop phenology and methodology of classifying main agricultural land abandonment based on ALOS-1 and 2 PALSAR multi-temporal measurements; and

3.3.3 To develop a methodology for semi-automated identification of abandoned oil palm lands using SPOT-6 image.

1.4 Scope of the Study

This study was designed within these identified scope:

1.4.1 To focus on three main crops in Malaysia which are oil palm, rubber and paddy;

1.4.2 To utilize multi-temporal of Landsat TM and OLI for crop phenology development, due to the availability of the Landsat TM and OLI historical data;

1.4.3 To perform object-oriented classification using Landsat TM and OLI, ALOS-1 and 2 PALSAR and SPOT-6; and

1.4.4 To implement the protocol at Mukim of Sungai Siput and Kuala Kangsar, Perak, due to the availability of ancillary data and permitted to access this area for field verification from FELCRA Berhad.

1.5 Outline of the Thesis

The layout of the thesis followed the Universiti Putra Malaysia alternative thesis format based on publications. Each research chapter (3 to 5) represent its own 'Introduction', 'Methodology', 'Result and Discussion' and 'Conclusion'. Hence, a specific chapter for methodology was not discussed.

Chapter 1
This chapter describes the subject matter and problems being studied. In addition, the specific objectives to be achieved and scope of the study were also mentioned.

Chapter 2
In order to fill in the research gap related to the use of remote sensing for detection and identification of abandoned land, comprehensive review on past research related to the subject matter was discussed in this chapter.

Chapter 3
This chapter presents the article entitled "**The Use of Multi-Temporal Landsat Imagery in Detecting Seasonal Crop Abandonment".** In this article, the capability of Landsat imageries in identifying abandoned paddy and rubber was explored.

Chapter 4
This chapter presents an article entitled "**Phenology and classification of agricultural land abandonment based on ALOS-1 and 2 PALSAR multi-temporal**

measurements". This article studied the characteristic of radar images in crop phenology and classification of abandoned paddy, rubber and oil palm.

Chapter 5
The third article included in this chapter entitled **"Towards the use of remote sensing data for monitoring of abandoned oil palm lands in Malaysia: A semi-automatic approach".** This article focused on abandoned oil palm monitoring using SPOT-6, a high resolution image.

Chapter 6
Finally, the overall conclusion and recommendation for future work were discussed in this last chapter.

1.6 Research Methodology Flowchart

Figure 1.1 shows the overall methodology flowchart for this research study, which consist of four primary stages i) data collection; ii) crop phenology development; iii) image pre-processing and classification; and iv) output. The primary data used were Landsat TM/OLI, ALOS-1 and 2 PALSAR and SPOT-6. In term of cost benefits, Landsat TM/OLI was the first data being explored, due to its free accessibility. However, as an optical data provider, cloud cover and atmospheric condition are inherited problems of Landsat. Thus, radar images derived from ALOS PALSAR-1 and 2 were used. In addition, SPOT-6 as a high resolution image was utilized, in order to achieve high accuracy for abandoned oil palm. Further, the research was performed with three main steps in order to meet the specified objectives. First, the development of crop phenology for paddy, rubber and oil palm, respectively, to using multi-temporal satellite images. Second, based on distinct crop phenology, appropriate image dates were chosen. Finally, rules set for object-oriented classification were developed according to the characteristics of crops in the respective satellite images. In addition, field verification was conducted for accuracy assessment, along with verification from Google Earth images. The accuracy of classification was assessed using sampling points collected through field validation, along with verification from Google Earth images. The selection of sampling points was carried out using the stratified random sampling with at least 30 points for each crop, abandoned or not. After the classification produced satisfied overall accuracy and standard error, the maps were produced with the minimum mapping unit of 0.4 ha.

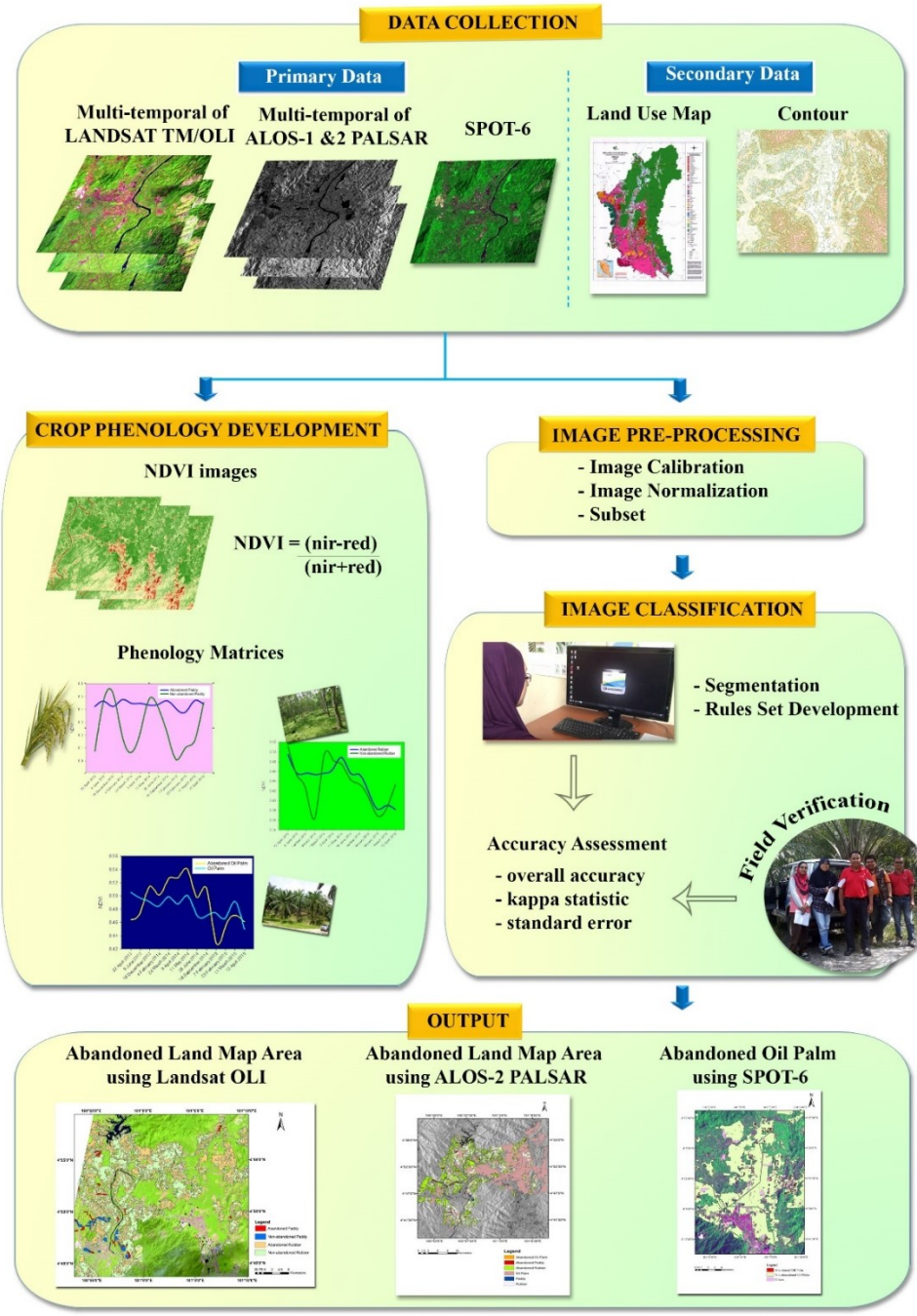

Figure 1.1: Research methodology flowchart

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