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DEVELOPMENT OF GEOGRAPHICAL INFORMATION TOOLS IN ROAD REALIGNMENT FOR OIL PALM PLANTATION

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By

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

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Oil palm replanting is essential in improving oil palm production and its cost efficiency. The vital elements in oil palm replanting are optimal agriculture road network and improvement of planting management. The traditional methods and current practices in developing agriculture road are time-consuming especially in a large area. In order to speed up the process, the Least Cost Path Analysis (LCPA) is proposed in this study. The study was carried out in TH Plantation located at Muadzam Shah, Pahang using Interferometric Synthetic Aperture Radar (IfSAR) data. Digital elevation models (DEMs) developed from IfSAR data is used to generate a slope map. By combining both of the slope factor and elevation factor, a Least Cost Path Analysis can be generated in order to find the optimal agriculture road network conditions. Sensitivity analysis is used to determine the percentage of influence in a Weighted Overlay tool. A model builder in ArcGIS collaborated with python language are then used to generate an automated system for producing optimal agriculture road network at the oil palm replanting area. Models developed in this context are workflows that chain together sequences of geoprocessing tools to automate the optimal agriculture road network management system. ArcGIS Python Add-In Wizard is used to develop tools that will be added in the existing standard ArcGIS tools and will be geospatial tools for oil palm plantation. In this study, the percentage of influence was assessed and determined before being used for the Weighted Overlay tool. It was tested using sensitivity analysis. Using this technique, 9 sets of data were tested. These data were compared and analysed into several criteria such as maximum elevation, maximum slope, length of the road, labour costing, time costing, and fuel costing. The result indicates that 60% slope and 40% elevation was good enough to be used as the Weighted Overlay tool percentage of influence. An LCPA tool was developed to be used as an extension tool in ArcMAP 10.3. The tool has been successfully developed and tested in ArcMAP 10.3 software. This tool allows the user to develop a

proposed agriculture road. When the tool was completed, T-test analysis was done to evaluate the effectiveness of the developed tool using several sets of the road network.

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PEMBANGUNAN ALAT MAKLUMAT GEOGRAFIK DALAM PENJAJARAN SEMULA JALAN RAYA UNTUK PENANAMAN KELAPA SAWIT

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Penanaman semula kelapa sawit penting dalam menambahbaik penghasilan dan penjimatan kos kelapa sawit. Komponen penting dalam penanaman semula tanaman kelapa sawit adalah jaringan jalan pertanian yang terbaik dan penambahbaikan pengurusan penanaman. Kaedah tradisional atau operasi semasa dalam mengembangkan jalan pertanian memakan masa yang lama terutamanya kawasan yang luas. Oleh itu, bagi mempercepatkan operasi, “Least Cost Path Analysis” (LCPA) dicadangkan dalam kajian ini. Kajian ini dijalankan di Ladang Tabung Haji yang terletak di Muadzam Shah, Pahang dengan menggunakan data “Interferometric Synthetic Aperture Radar (IfSAR). Data “Digital elevation models” (DEMs) yang terhasil dari IfSAR digunakan untuk membuat peta cerun. Dengan menggabungkan faktor cerun dan juga faktor ketinggian, LCPA boleh dihasilkan bagi mencari keadaan jaringan jalan pertanian yang paling terbaik. Analisis kepekaan telah digunakan bagi menentukan peratusan pengaruh dalam teknik “Weighted Overlay”. Pembina model dalam aplikasi “ArcGIS” digabungkan dengan bahasa arahan “python” yang kemudian digunakan untuk menghasilkan sistem automatik yang berupaya menjana jaringan jalan pertanian di kawasan penanaman semula kelapa sawit. Dalam konteks ini, model yang dihasilkan adalah susunan kerja yang menyambungkan beberapa urutan instrumen geoprosesan bagi menghasilkan sistem pengurusan jaringan jalan pertanian yang terbaik secara automatik. “ArcGIS Python Add-In Wizard” digunakan untuk membina suatu instrumen yang mana ditambah dalam instrumen biasa “ArcGIS” yang sedia ada, yang akhirnya akan menjadi instrument “geo-spatial” untuk ladang kelapa sawit. Dalam kajian ini, peratusan pengaruh ditentukan dan dinilai sebelum digunakan untuk instrrumen “Weighted Overlay” dengan membuat ujian menggunakan analisis kepekaan. Dengan menggunakan teknik ini, 9 kumpulan data telah dibuat ujian. Seterusnya, data-data ini dibandingkan dan dianalisis kepada beberapa kriteria iaitu ketinggian maksimum, cerun maksimum, jarak jalan, kos pekerja, kos masa, dan kos bahan api. Hasil kajian mendapati

bahawa 60% cerun dan 40% ketinggian adalah yang terbaik untuk digunakan sebagai peratusan pengaruh dalam instrument “Weighted Overlay”. Instrumen LCPA telah dibuat untuk digunakan sebagai sambungan instrument dalam aplikasi ArcMAP 10.3. Instrumen ini telah berjaya dikembangkan dan diuji dalam aplikasi ArcMAP 10.3. Dengan menggunakan instrumen ini, para pengguna boleh menghasilkan jalan pertanian yang diingini. Apabila instrumen ini telah siap, analisis “T-test” telah dijalankan untuk menilai keberkesanan instrumen yang telah dihasilkan dengan menggunakan beberapa kumpulan data jaringan jalan.

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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LIST OF ABBREVIATIONS

°	degree
BMP	Best management practices
CAD	Computer-aided design
CL	Coefficient of localization
DEM	Digital Elevation Model
DGPS	Differential Global Positioning System
DSM	Digital Surface Model
DTM	Digital Terrain Model
EDM	Electronic distance measurement
FELDA	Federal Land Development Authority
FFB	Fresh fruit bunch
GIS	Geographic Information System
GPS	Global Positioning system
Ha	Hectare
hr	hour
IDE	Interactive development environment
IfSAR	Interferometric Synthetic Aperture Radar
INS	Initial Navigation System
km	Kilometre
L	Litre
LCPA	Least Cost Path Analysis
LQ	Location Quotients
m	Metre
ORRIs	Ortho-Rectified Radar Images

RM	Ringgit Malaysia
SAR	Synthetic Aperture Radar
TLMs	Topographic Line Maps

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Geographical Information Systems (GIS) is a computer system that virtually save any data and information found on a paper map virtually. However, it can be much more useful than a traditional map. While GIS can present a map on a computer display, it can also offer complete information about their characteristics, such as name, dimension, area, and many more. In addition, GIS is a method that utilize computer system by taking, saving, evaluating, and demonstrating geographically referenced information which is data known corresponding to position. Furthermore, it can integrate various mapped variables to develop and explore new variables. The computer system in GIS can search fast and evaluate map variables and their attribute in a way that are impossible to do it in paper maps. GIS can also assist users to understand the solution to their problems and solve the problems by showing data in simple graphic ways.

Because of the advancement in GIS, there are many advantages that you can find when using it. GIS can help users to improved decision making. By using particular and detailed information about one or more locations, analysis can be done and it makes users easy to decide. As an example, by using GIS, estate manager can easily select the best site selection and extract natural resources. Nowadays, industry is starting to understand that making the correct decision about the strategic location is key to the success of an organization. Another major advantage of GIS are it reduces costs and increase efficiency. Cost reduction is defined as decreasing expenses in operating by the organization. It is done by savings in time when the survey operator performing their tasks or works more efficiently. GIS is now being widely used in almost everything and everywhere including in oil palm estate.

Oil palm (*Elaeis guineensis*) is a perennial monocotyledons plant, largely grown in tropical countries such as Africa, Latin America, and Southeast Asia. Oil palm is grouped in the Arecaceae family along with coconut and date palms. Oil palm trees are single-stemmed and can shoot up to 20 m tall when mature. The leaves are pinnate and reach between 3 m and 5 m long. Since oil palm tree is a tropical palm tree, it can be grown easily in Malaysia due to the tropical climate. Oil palm plays a vital role which acts as one of the main economic crops in Malaysia. In 2011, the oil palm industry was the fourth biggest source to Malaysia's economy, accounting for RM 53 billion (USD 16.8 billion) of Malaysia's Gross National Income. Malaysia produced 18.63

tonnes/hectare of oil palm fresh fruit bunch for 5.39 million hectares. The oil palm sector has contributed to the wealth of Malaysia.

In general, oil palm will make its highest yield of fresh fruit bunch (FFB) during the sixth to the twelfth year after planting. After that, the yield will slowly drop. The decrease in palm oil yield will cause losses to some of the profit margins. In Malaysia, oil palm has taken a large part of the land, particularly in private plantations, which reached an average age of 20 economic years life span specifying that there is a need for oil palm replanting. Oil palm replanting offers an opportunity for the estate management to improve performance of the existing system accessibility for mechanization and road re-alignment, planting density, and drainage system. Furthermore, it is also can help to deal with the harvesting problem, low yield, and current prices of oil palm product. Replanting is a very influential aspect for the cultivation of oil palm and it is one of the useful practices to enhance oil palm productivity.

1.2 Problem Statement

Research has been conducted to explore the potential of Geographic Information System for oil palm plantation management. Figure 1 shows the common oil palm replanting workflow that is already practised in FGV & FELDA. The current practices are very time consuming and some of the methods are done manually such as constructing roads in the hilly area. The current method to construct plantation road is done by using surveying method which involved the usage of theodolite or inclinometer. The area was considered as flat area when the slope is from 0° to 6° and plantation operator need to manually measured then mark that area. The process is repeated until a network of plantation road is formed. This process is time consuming especially in a big area (Abd Aziz et al., 2013).

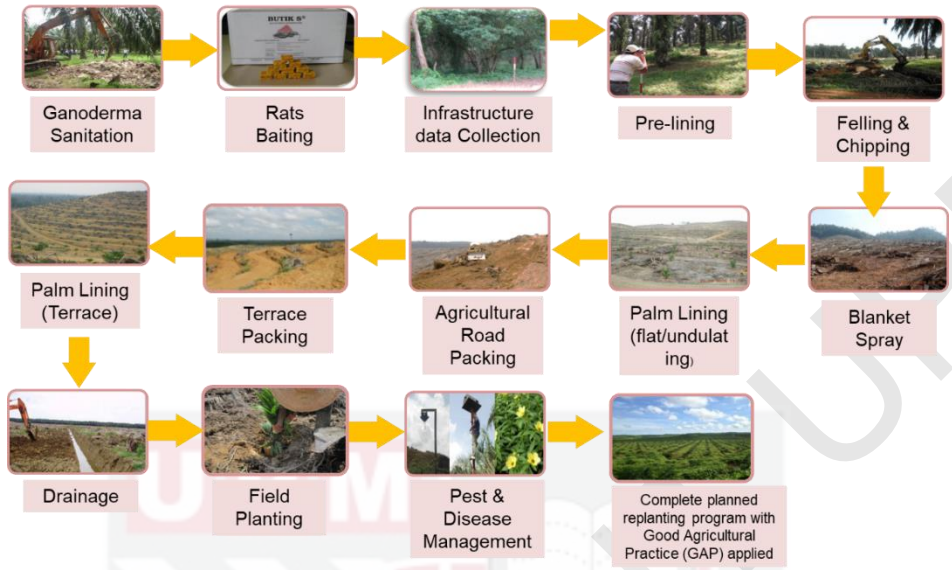

Figure 1: Common oil palm replanting workflow

To increase the efficiency of the current oil palm replanting work flow, new methods by using GIS is really needed and crucial. This study will propose the design of optimal agriculture road based on elevation and slope parameter using GIS, develop spatial decision support tool for road re-alignment in oil palm plantation and then evaluate the effectiveness of developed tools using set of road network.

1.3 Objectives

The aim of this study is to develop Geographic Information System tools to help in the better management of the oil palm plantation. There are several objectives to accomplish in this project which are:

1. To design optimal agriculture road based on elevation and slope parameter.
2. To develop spatial decision support tool for road re-alignment in oil palm plantation.
3. To evaluate the effectiveness of developed tools using set of road network.

1.4 Scope and Limitations of the Study

This research is aimed on the development of Geographic Information System tools to assist plantation manager in decision making. The system will let users design optimal agriculture road uisng LCPA model which is based on the

Interferometric Synthetic Aperture Radar (IFSAR). The LCPA model is developed by using a model builder in ArcMAP 10.3 software. This research was done in Tabung Haji Plantation situated at Muadzam Shah and only cover two blocks which are Sg. Mengah and Kota Bahagia block plantation.

Although the study has reached its objectives, there were some inevitable limitations. IfSAR data is used as input for the least cost path analysis with the accuracy of 5 m. This will affect the result of the analysis. Therefore, to get better results, the study should have used LiDAR data which is more accurate and its accuracy is up to cm level. Second, optimum agriculture road is based on slope and elevation parameter only. Due to time constraint, this study is focused on the development of agriculture road on the main road only. Lastly, all the calculations regarding costing are just estimated value.

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