Paper No :

MSAE2018-ARWM020

Geographic Information System: Least Cost Path Analysis for Oil Palm Plantation

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ABSTRACT

Oil palm industry is one of the major contributor to Malaysia's economy. Good oil palm management is needed to sustain the industry. One of the main factor to ensure good oil palm management is oil palm replanting. It is essential in improving oil palm production and cost efficiency. The vital elements in oil palm replanting are optimal agriculture road network and improvement of planting management. Development of optimal agriculture road network is important to ensure the effectiveness of fresh bunches collection. The aim of this study is to design optimal agriculture road based on elevation and slope parameter. Hence, it will improve the planting management and give benefits to the management in preparing the budgets and new contracts for a new oil palm plantation. Digital elevation models (DEMs) resulting from Interferometric Synthetic Aperture Radar (IfSAR) is used to generate a slope map. Combining elevation map, slope map and land use map, a Least Cost Path Analysis (LCPA) is developed to find optimal agriculture road network. It is a distance analysis tools within Geographic Information System (GIS) that create path between two locations that costs the least to those travelling along it, thus determine the most cost-effective route between a source and destination. From the results, it showed that road path produced from LCPA was shorter and away from unnecessary slope and elevation. Road profiles such as elevation, slope, and length were analysed, and it clearly showed that LCPA has potential and played an important role in modelling of oil palm plantation road allocation efficiently and reduced time consuming. The New Road model facilitates shorter displacement, less undulating elevation and declining in slope compare to the existing road.

KEYWORDS

DEM, GIS, IfSAR, LCPA, Replanting model.

**Paper presented at the 2018 MSAE Conference, Serdang, Selangor D. E., Malaysia.
7 & 8 February 2018**

INTRODUCTION

In general, oil palm will make its highest yield of FFB on the sixth to twelfth year after planting. After that, the yield will slowly drop. The decrease in palm oil yield will also decrease the profit margin. In Malaysia, oil palm has taken a large part of the land planted with it, particularly in private plantations, has reached 30 economic year life span specifying that there is a need for oil palm replanting (Ismail & Mamat, 2002). Oil palm replanting offers an opportunity for the estate management to improve performance of the existing system such as accessibility for mechanization, road re-alignment, planting density, and drainage system. Furthermore, it also can assist in improving harvesting problem, low yield, and postharvest losses of oil palm product. Hence, it will improve the agricultural road so that fuel consumption can be reduced and increase the work effectiveness.

(Kamaruzaman & Shamsul, 1999) had stated that the traditional method in preparing road plan and drawing needs several step preparations, designing and planning which these steps need massive labour, time consuming and expensive costing. The complexity of development and design of the plantation road has provided the traditional method of planning improvements in the future. Thus, new method is needed which is more efficient and economical that is able to perform the requirement for mapping, planning, and design oil palm plantation road (Abd Aziz et al., 2008). Recent technologies introduced by GIS together with Remote Sensing application has proved it can adopt the ability of computer programming for design and planning of oil palm plantation road network. Besides, the development of necessary features in oil palm plantation can be made easy such as streams, irrigation system, and mapping of regions with tendency of having landslide and soil erosion. The potential of GIS in mixing of spatial and non-spatial information has made it very useful tools in plantation road planning.

Cost, time, efficiency, and distance are crucial aspects in the oil palm plantation industry. Network analysis is practical in finding the minimum distances, time, or expense in travelling from one point to another in network. In terrain area, traditional method has big disadvantages in plantation planning because of very time-consuming and costly, hence it will be difficult to operate in the future, but it can be performed by using computer information system. (Meng, 2006) suggested that construction of main forest road can be mapped and designed in GIS thus we want to test the potential of this method in oil palm plantation management. (Abd Aziz et al., 2008) had stated that GIS application in oil palm management can be broadly used in plantation road planning, operation management, and costing management. The purpose of this study is to test the potential of GIS in modelling oil palm plantation road in Kota Bahagia Tabung Haji Plantation, Muadzam Shah, Pahang. Then, this study will evaluate road profile produced by GIS method (new road) with the existing road and assigns the best path road from source to the palm oil mill.

MATERIALS AND METHODS

Study area

The study area was located at Kota Bahagia Tabung Haji Plantation. It is situated in the district of Muadzam Shah, Pahang (Figure 1). This plantation is divided into three sub-plantations which are Ladang Kota Bahagia, Ladang Sungai Mengah, and Ladang Sungai Buan. This plantation was selected as a study area due to the nature of this area that had been historically and currently planted with oil palm.

ISBN 978-967-16145

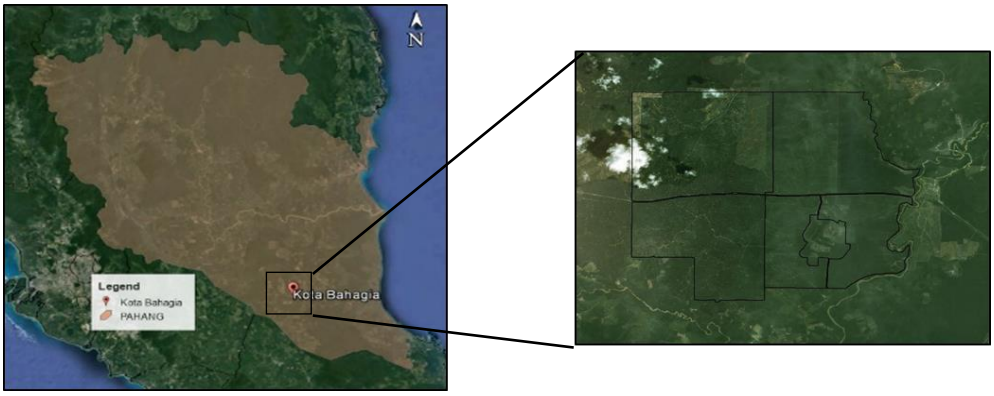

Figure 16: Location map of the study area

Data preparation and analysis

The IfSAR data were acquired from a mapping services provider. The data is already filtered and consist of Digital Surface Model (DSM) and Digital Terrain Model (DTM). Basically there are two type of data that were used in the least cost path analysis model which are elevation and slope. New oil palm plantation road was produced from re-classification of the two layers. Table 1 indicated classification of each data to be used in the least cost path analysis.

Table 5:Classification of grid layer for Least Cost Path Analysis

Parameter	Class range	Class factor	Verbal Class
Slope (degree)	0-3	1	Flat
	3-6	2	
	6-9	3	Rolling to undulating
	9-12	4	
	12-15	5	
	15-18	6	Steep
	18-21	7	
	21-24	8	
	>24	9	Hilly
Elevation	0-10	3	Low
	10-50	2	Moderate
	50-100	1	High

Thematic layers were created based on each class which are elevation and slope and determine by cost weighted of maps. The two layers will be ranked according to its class range. Class range is determining by the value of respective parameter. Each parameter is weighted according to its importance or its percent influence. A cost weighted overlay method is decided by assigning 60% weightage to slope and the remaining 40% is for DEM and its formula is shown in following equation:

[0.6 x (slope) + 0.4 (elevation) as grid] (Equation 1)

Least Cost Path Analysis model

All parameter layers were converted to the cost maps and they are ready for cost distance evaluation. The following step is to find agriculture road path between source and target. It calculates the least accumulative cost distance from a source for each cell to the nearest over a cost distance. In this model the selection of source and target may influence the output of the road alignment. From the weighted overlay function, the path was constructed to give a raster direction of the least cost path for each cell from source to target. Once the cost distance and path of raster were created, the best route to reach the destination target were created automatically. Based on the least cost path analysis model, it can allocate the best path alignment for the study area. The model generates a new file of the area by giving new

raster values to all cells. The value is equivalent to the value of nearest between source and target. The outline of the processes is shown in Figure 2.

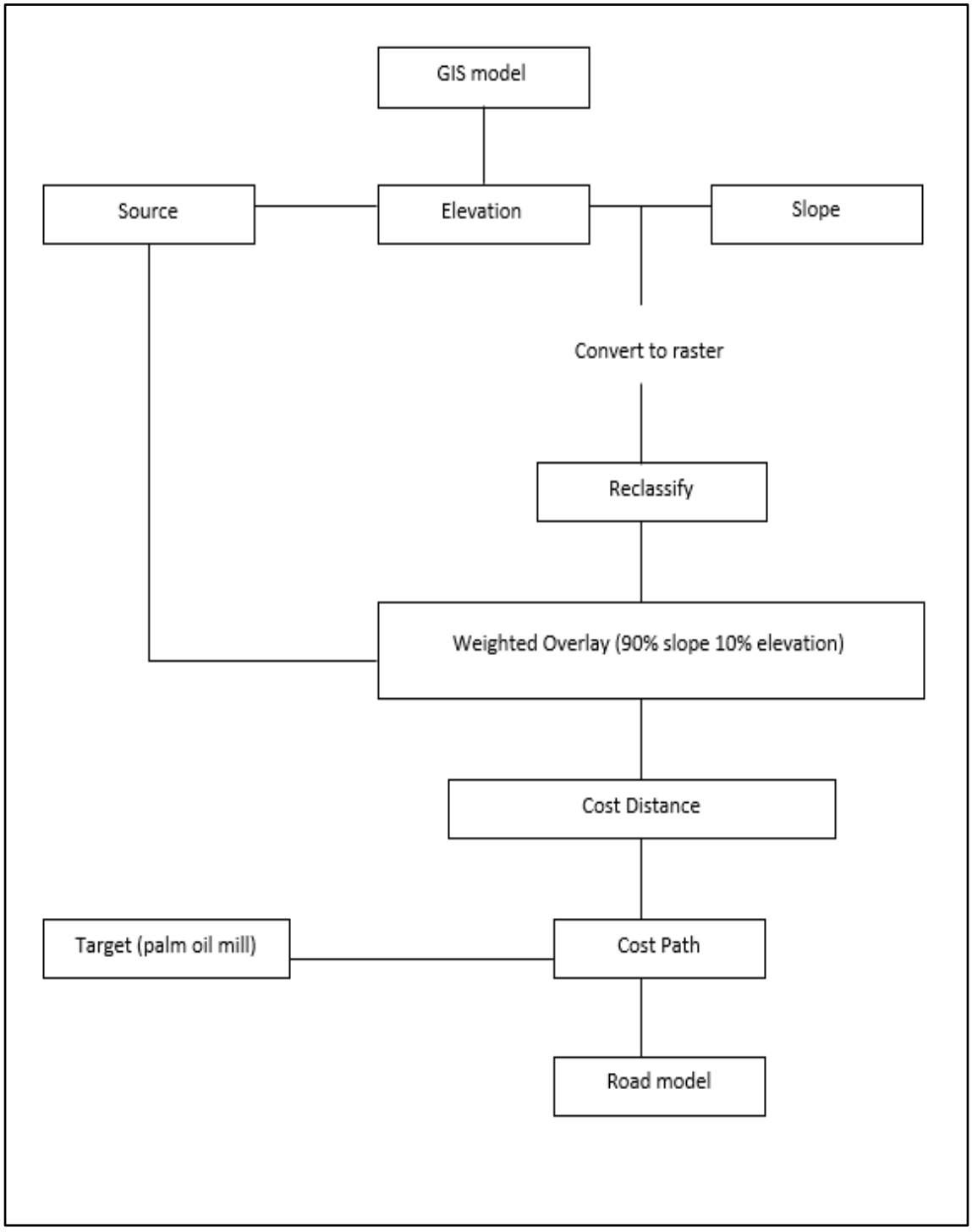

Figure 17: A simplified chart for the model

ISBN 978-967-16145

RESULTS AND DISCUSSIONS

The oil palm road network model showed in Figure 2 are tools to aid the oil palm plantation manager consider the effectiveness and also help to determine best possible location for a plantation road network, as considering and determining the transportation aspects, slope, and other topographical element of the study area. Figure 3 showed the result from the road alignment model. It calculates from the source to the target (palm oil mill). The road alignment model gave better result as presented in Table 2.

Table 6: Profile for the existing road and new road (model)

	Max. elevation (meter)	Max. slope (degree)	Distance (meter)
Existing road	91.75	26.49	9530.30
New road(model)	88.60	14.98	7434.10

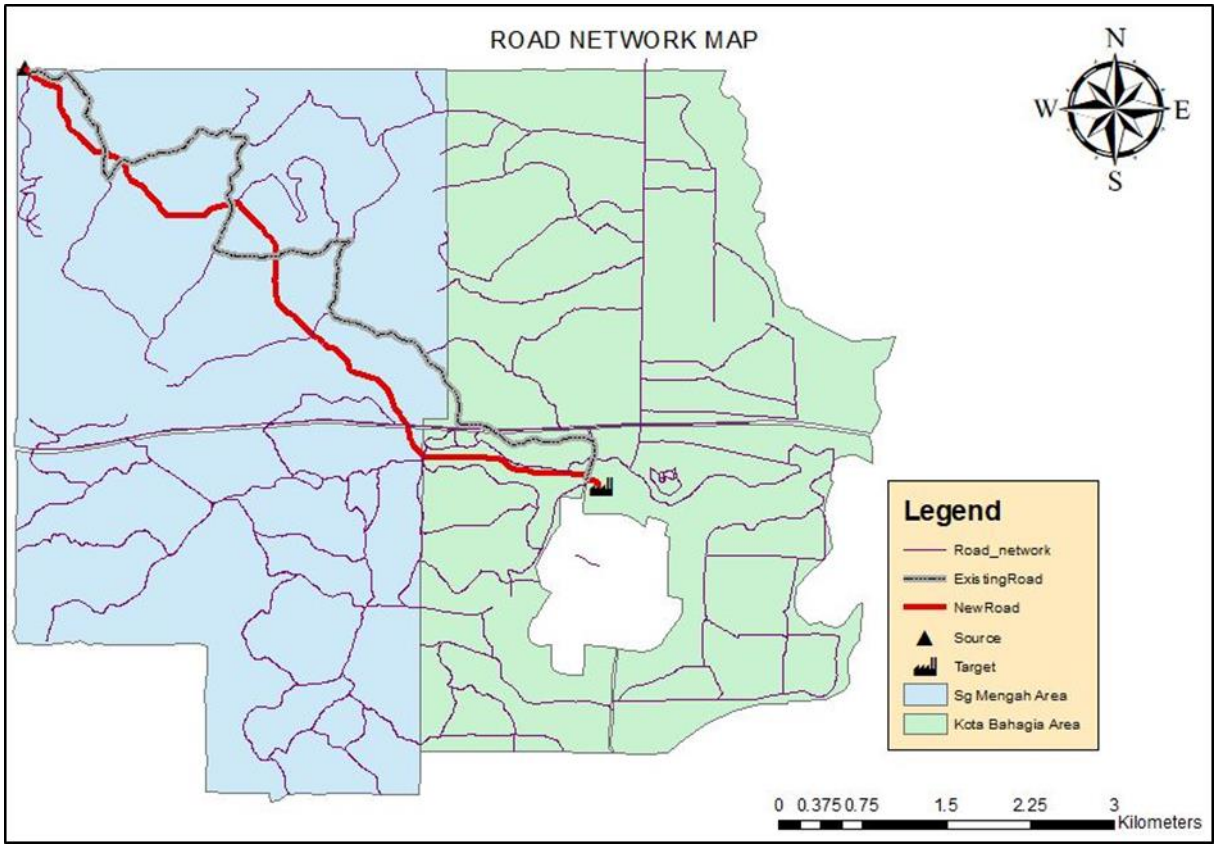

Figure 18: New road (Model) overlay with existing oil palm plantation road

The red line showed in Figure 3 was produced automatically from the road alignment model, on the other hand the dotted grey line was the existing oil palm plantation road through digitizing method in ArcMAP. Main idea is that automatic road alignment developed from this model generated qualitative spatial reasoning. The length produced using route modelling was 7434.10 meter while the existing road length is 9530.30 meter. From the value, it is showed that the new road derived from the model give shorter length by 2096.20 meter. For the slope, maximum slope in the existing road alignment was 26.49 degree and 14.98 degree for the new road alignment, which the difference was 11.51 degree. The maximum elevation for existing road was 91.75 meter and 88.60 meter was the maximum elevation for new road alignment.

CONCLUSIONS

From this study, numerous conclusion can be drawn; firstly, GIS method had showed its capability to be operated in oil palm plantation road planning because it can be used as a base map for considering optimal alignment of oil palm plantation road. Furthermore, it is practical to use it in early planning processes. Oil palm plantation road that generated from the using GIS method gave less ecological impacts on soil degradation since it high risk area or problematic area were evaded because the road that had been developed only go through low and moderate class area which the slopes do not surpass 14.75 degree and height below than 82.80 meter. GIS method must be used these days because it will give fast and satisfying result, easy to operate, and low cost for road alignment in oil palm plantation. Moreover, oil palm plantation road map has capability to assists in calculate cost of road maintenance, road quality and, other aspects that related to plantation operations.

ACKNOWLEDGEMENT

This study was supported by grants from Putra IPB grants under University Putra Malaysia. We thank to Tabung Haji staff for providing assistance and sites for this research.

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