EFFECTS OF DEMs FROM DIFFERENT RESOLUTIONS IN DERIVING STREAM NETWORKS THRESHOLD VALUES AND MORPHOMETRIC ANALYSIS

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by

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LIST OF ABBREVIATIONS

ASTER	Advanced Spaceborne Thermal Emission Reflection Radiometer
AVHRR	Advanced Very High Resolution Radiometer (AVHRR)
CGIAR-CSI	Consultative Group for International Agriculture Research–Consortium for Spatial Information
DEM	Digital Elevation Model
DID	Department of Irrigation and Drainage Malaysia
ERS	Earth Resources System
GIS	Geographical Information System
GCP	Ground data control points
GPS	Global positioning system
IDW	Inverse Distance Weighing
IFSAR	Interferometric Synthetic Aperture Radar
JUPEM	Department of Surveying and Mapping Malaysia
LiDAR	Light detection data
ME	Mean error
NASA	National Aeronautics and Space Administration
NIMA	National Imagery and Mapping Agency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar (SAR)
SRTM	Shuttle Radar Topographic Mapping
SPOT	Satellite Pour I'Observation de Terre
SWAT	Soil and Water Assessment Tool

SWIR	Shortwave Infrared
TIR	Thermal Infrared
TIN	Triangulated irregular network
Topo to Raster	Topographic DEM
USGS	U.S. Geological Survey
USACE	United States Army Corps of Engineers
VNIR	Near Infrared

LIST OF SYMBOLS

A	Area
(Rb)	Bifurcation ratio (Rb)
(Rc)	Circularity ratio
(R^2)	Coefficient of determination
(Dd)	Drainage density
(T)	Drainage Texture
(Re)	Elongation ratio
(Ff)	Form factor
(Δh)	Height differences
z	Height of watershed mouth
A	Inductance ratio
L	Length
Z	Maximum height of the watershed
(Rbm)	Mean bifurcation ratio
n	Number of checked elevation points
Zo	Observed elevation
Zp	Predicted elevation
(Rr)	Relief ratio
S	Standard deviation
Sb	Slope
U	Stream order
(Lu)	Stream length
(Fs)	Stream frequency

Nu	Total stream no
H	Total watershed relief
P	Perimeter

PENGARUH KETINGGIAN BERDIGIT DARI RESOLUSI YANG BERBEZA DALAM MENDAPATKAN RANGKAIAN NILAI AMBANG ALIRAN SUNGAI DAN ANALISIS MORFOMETRI

ABSTRAK

Penggunaan Model Ketinggian Berdigit (DEM) terhadap kajian kawasan tadahan air telah diterima dan digunakan dalam pelbagai aplikasi yang melibatkan kajian hidrologi. Walau bagaimanapun, terdapat cabaran terhadap penentuan ketepatan permukaan topografi sesuatu kawasan dimana penggunaan kajian berasaskan lapangan dalam menentukan permukaan topografi mengambil masa yang agak lama. Oleh itu,kajian ini telah dijalankan untuk mengkaji dan menilai ketepatan ketinggian pelbagai model berdigit terhadap rangkaian aliran sungai. Kajian ini telah mengenalpasti penarafan ketepatan ketinggian model ketinggian berdigit daripada pelbagai sumber dan resolusi yang berbeza. Sumber DEM daripada SRTM, ASTER, NEXTMap World 30 dan peta topografi telah digunakan dalam kajian sebagai penilaian dan perbandingan ketepatan. Ralat Punca Min Kuasa Dua (RMSE) diperolehi dalam penilaian ketepatan tegak. Hasil kajian menunjukkan nilai RMSE untuk SRTM ialah ± 8.15 m, ± 8.68 m untuk ASTER, dan ± 7.98 m untuk NEXTMap World 30, telah berada dalam kebolehtelapan yang dibenarkan oleh USGS. Seterusnya, kajian aliran sungai menggunakan SRTM 30 m menunjukkan hasil yang serupa dengan kajian yang dilakukan oleh Jabatan Pengairan dan Saliran Malaysia. Sementara itu, hasil analisis membuktikan bahawa rangkaian saliran dari SRTM 30 m dengan nilai ambang 40 adalah paling hampir dengan saliran rujukan. Hasil kajian telah memberi petunjuk kepada nilai-nilai ambang yang berkesan dan sesuai untuk analisis rangkaian aliran sub-lembangan sungai masa hadapan.

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ABSTRACT

The use of Digital Elevation Model on the watershed survey has been accepted and applied in various applications involving hydrological studies. However, there is a challenge to determine topographic surface accuracy in the areas where the use of ground-based topographic surface studies takes a long time. Therefore, this research was conducted to study and determine the height accuracy from multiple digital models over network of streams. The study has determined the height accuracy rating of the digital elevation model from various sources and different resolutions. DEM sources from SRTM, ASTER, and NEXTMap World 30 and topographic maps were used to assess and compare the accuracy. The Root Mean Square Error (RMSE) was acquired in the vertical accuracy assessment. The results show that the RMSE value for SRTM is ± 8.15 m, ± 8.68 m for ASTER, and ± 7.98 m for NEXTMap World 30, are within the permissibility allowed by the USGS. Subsequently, the river flow study on the SRTM 30 m establishes a similar result with the study performed by the Malaysian Drainage and Drainage Department. Meanwhile, the analysis reveals that the drainage network from SRTM 30 m with threshold values of 40 was closest to the referenced drainage. The result has signifies the most appropriate values for an effective stream threshold network to be considered suitable for future river sub-basin analysis.

CHAPTER ONE

INTRODUCTION

1.1 Research Background

Digital Elevation Model (DEM) has been commonly incorporated in many research involving various forms of surface topography. DEM that is produced from the aerial and satellite imageries are photographic representation of the earth (Korsgaard et al., 2016). The first satellite photograph of earth was taken from the US satellite Explorer 6 in 1959. Based on the report by the USGS, the emphasis on DEM studies started from USGS USA which presented the topography across the United States (Wang and Wade, 2008). DEM study has undergone the evolution and development utilities around the world. It can then be deduced that DEMs have gradually gained the interest of many which encompass digital topographic data.

Subsequently, the development of satellite data showed an enormous growth in the number of mapping topography. Examples are Satellite Pour I'Observation de Terre (SPOT), Earth Resources System (ERS) and RADARSAT. DEM could be freely acquired from Shuttle Radar Topographic Mapping (SRTM), GOTO30, ASTER GDEM, and Cartosat-1 (Patel et al, 2016). DEM is a main topographic product and becomes a crucial demand for many applications (Polat et al., 2015). DEM has positively impact various applications, mainly in land and water resource. Besides, DEM is highly capable in obtaining various forms of data from low to high resolution in order to assist researchers in the development of various applications such as river network delineation, flood modeling, geology, forestry, and hazard mapping.

(Hosseinzadeh, 2011). For instance, the blueprints of the drainage system and catchment boundary which include various characteristics such as aspects, slope and contour have mainly utilized DEMs (Rahman et al., 2010).

Studies on accuracy assessment between various data sources have been extensively performed towards DEM in a large scale which is emphasized at a regional scale over rural and urban areas (Pulighe et al., 2015). Therefore, in a crucial application using various DEM, accuracy assessment is implemented mostly to conduct dissimilarity analysis where open-sourced DEMs consist of multiple grid cell size resolution datasets which determine the quality to derive topographic analysis. Realizing that accuracy assessment is an important part in DEM method, an initiative was taken to implement in the river stream network to highlight the importance of accuracy in computing watershed delineation and stream network.

The Department of Irrigation and Drainage Malaysia (DID) was established to monitor and to solve any issues which are related to river catchment management and streamflow data (DID, 2010). Basically, it is relatively dependent on the national agency's (e.g., DID) data stream network since all dataset are collected through surveying river network in the field yet costing a large amount of money (Li and Wong, 2010). Therefore, instead of relying on the traditional surveying in the field dataset, the objective of this research is to examine the competency by utilizing a diverse set of DEMs data based on the constructive approach in generating river stream network.

Although DEMs can be potentially generated in constructivist-derived river stream network, they also have tremendous advantages which are relevant to the river stream. This will facilitate a deeper understanding and analysis. According to (Vaze et al., 2010), it is perceived that the ability of DEM in generating river network delineation cannot be denied. Moreover, the cost and time requirement are less than the traditional methods. Despite that, contrasting outcomes can be obtained when the utilization of different DEM resolution on the topographic features and hydrology is investigated. Past studies on identifying the effects of topographic and hydrological attributes onto small watershed DEMs towards from northern Idaho have been thoroughly reviewed by (Zhang et al., 2008).

In a specific study, six DEMs were utilized and the different resolutions of DEMs have produced diverse structures and shapes of watershed which provided different channel length and extracted hillslope. Further research is needed to investigate how stream network threshold value should be a component of DEM sensitivity towards river network studies. According to (Ariza-Villaverde et al. 2015), there is a significant and strong relationship between DEM resolution and threshold value in river network studies. Hence, the research objective is to study the different DEM resolution coupled with the geographical information system (GIS) and to examine the potential of this tool in assessing the extraction drainage river stream network.

1.2 Problem statement

The sensitivity of Digital Elevation Model (DEM) has been in the limelight due to the differing spatial resolution which offered different results in river network applications. (Li and Wong, 2010) claimed that some studies using different data sources has experienced problems in analyzing the stream network and failed to provide consistent results due to different spatial resolutions.

Specifically, in the stream network studies, the spatial resolution of DEMs is an essential part in extracting the river network as the resolution and precision have genuine ramifications towards hydrological parameter. (Jana et al., 2007 stated that although DEM has been acknowledged as sensitive towards resolution, the interpolation method has to be taken into account as this will influence the outcome of DEM accuracy. In particular, the report has found weaknesses in the method of interpolation and concluded that the DEM often contains errors in flat areas.

In addition to the weaknesses reported by (Jana et al., 2007), a study by (Sharma et al., 2010) revealed that it is difficult to understand or explain as the interpolation method or cell size of resolution is plausible in affecting DEM accuracy whilst hydrological application passively depends on DEM accuracy. However, extracting drainage network is often strongly dependent on the high quality of DEMs resolution for it to be an effective method to determine the topographic contours, computing elevation slope, and aspect (Liu and Zhang, 2011).

Furthermore, few researchers in Malaysia are interested in exploring the issue of DEM sensitivity towards river watershed. (Tan et al., 2015) conducted a study on the sensitivity of DEM resolution and using different DEM sources and DEM resampling techniques. Nevertheless, the stream networks threshold values are often left out in the discussion. These views are consistent with those of (Bhowmik et al., 2015), when they claimed that stream network threshold generally enhances the effectiveness and benefit analysis when it comes to stream network studies, but frequently misses out when a comparison between the pervasiveness of traditional field survey approach and stream network generate from DEMs is made.

Therefore, in such situations, the stream network threshold parameters should be highlighted beside the DEM resolution which emphasized digital stream network mapping by conducting an assessment in improving accuracy, precision, and efficiency. It is important to quantify these perceived changes in resolution to which these changes could lead to accurate river networks, thus, the watershed stream network delineation can be improved. Table 1.1 shows previous method use to compare with current study.

AUTHORS	METHOD	NUMBER OF DEM USED	THRESHOLD USED
Singh et al., 2014	• Extract the river network from DEMs • Extract all river parameters and using ArcGIS • Compute the morphometric parameters	2	X
Vaze et al., 2010	• Compared DEM data with field survey elevations point. • Compare the stream network and watershed with single DEM with multiple resolution.	1	X
Li and Wong, 2010	• Nearest neighbour resampling. • Extract river from different sources of DEMs • Compares extracted river networks with National Hydrography Dataset (NHD)	3	X
Li, 2014	• Extract watershed boundary and stream network data from National Hydro Network (NHN) • Using Arc Hydro tools in ArcGIS	1	✓
Current study	• Extract the river networks from multiple DEMs and resolution. • Compute the morphometric parameters	4	✓

Table 1.1 Previous method compared with current study

1.3 Scope of study

This study attempts to quantify the relative relationship between various open-source Digital Elevation Models (DEMs) and stream network delineation response towards sample of watershed along the Seberang Perai River. An accuracy assessment was conducted in order to achieve the main purpose. DEMs accuracy is tremendously important to calculate the ambiguity of terrain parameters such as slope, aspect and basic information in order to estimates errors in drainage maps (Tobergte and Curtis, 2013). Therefore, spot height from the Department of Surveying and Mapping Malaysia (JUPEM) as an independent ground truth data are required to compare with open-source DEMs.

Attention was given at variances in threshold number resulting from the replacement of DEMs resolution. This research focuses on geomatics perspective and without the involvement of hydrological or flood modelling. The semi-distributed HEC-GeoHMS tool in ArcGIS was employed to create a stream drainage network analysis model for the Seberang Perai River watershed. The model was then conducted to find the differences in the plausible effect on streamflow. The river network data were extracted from the Department of Irrigation and Drainage Malaysia (DID). Further datasets have been compared to extracted river stream network from various open-source DEMs. The effectiveness of stream drainage network extracted from multiple DEMs was evaluated based on stream threshold and morphometric parameter.

In order to explore these concerns, the following research questions are outlined:

- What is the extent of changes in resolution effects among various DEMs?
- How to measure the accuracy assessment?
- Which is the best reading for accuracy assessment among the various datasets?
- What is the most suitable method to extract the stream network?
- What are the factors that may affect the pattern?
- Are the morphometric parameters adequate to represent the different resolution of stream network analysis?

1.4 Aim and Objectives

This study aims to understand the accuracy assessment of multiples resolution DEMs datasets effects towards river stream network. Based on the postulated research questions, the following research objectives are formulated:

1. To determine the effects of the resolution of various DEMs sources through the vertical accuracy assessment.
2. To measure the influence of stream order and threshold number towards stream network formation extracted from the various DEMs sources.
3. To extricate and quantify the linear, areal, relief parameters derived from DEMs on drainage sub-watershed of study area.

1.5 Area of Study

Pulau Pinang is located at the northern area of Peninsular Malaysia and is bordered by Kedah to the north and east, to the south by Perak and to the west by the Strait of Melaka. The total area of Pulau Pinang is 1,031 km2 or with a total population of 1.70 million (Malaysia Statistics Department, 2015). It consists of five districts such as Northeast and Southwest districts for island besides Seberang Perai. The Seberang Perai district is further subdivided into three districts which are Central Seberang Perai District, South Seberang Perai District, and North Seberang Perai District. The major economic activities in Pulau Pinang State are manufacturing-based, mainly the high-tech electronics plants, automotive industry, and shipping which contributed 13.6% to the Malaysia manufacturing sector (Malaysia Statistics Department, 2013). Agriculture and livestock farming are also important occupations found in this area. This research will focus on the river in South Seberang Perai District and Central Seberang Perai District for DEMs accuracy and stream network analysis.

The Jawi river watershed and Mengkuang Dam were chosen to perform the analysis. The Jawi river watershed is situated in South Seberang Perai and is one of the major watersheds and consists of sub-watershed rivers, namely, Bakap River, Duri River, Baung River, Badak Mati River, and Bakar Arang River (DID 2010). The Jawi river system flows through major towns such as Bukit Tambun and finally discharging into the Strait of Melaka. The average of the study area is dominated by both undulating and flat land which is generally covered by agricultural fields.

Mengkuang Dam is located at Central Seberang Perai District and is the only water dam at Seberang Perai. According to (Maznah and Makhlough, 2015), 80% of drinking water have been supplied to the Penang state and received almost 90% of water input from the Kulim river. Since the drought season causes an inadequate supply of raw water, the Sungai Dua water treatment plant is supplied with raw water from the Mengkuang dam (Sallet et al., 2011). The dam catchment is surrounded by Taman Rimba Bukit Mertajam hills and receives heavy precipitation in the form of rainfall, most of which occurs from October to December. The terrain surface of surrounding area is suitable to study on the accuracy assessment in different resolution. Figure 1.1 shows the whole study area for Seberang Perai Tengah and Seberang Perai Selatan. This figure provides detailed for objective 1 which emphasis on vertical accuracy assessment. Meanwhile, Figure 1.2 shows the study area associate with objective 1 and 2. The study area comprise of 2 watershed where Mengkuang watershed located at Seberang Perai Tengah (SPT) and Jawi watershed is located in Seberang Perai Selatan (SPS). Both watersheds are shown in shaded areas.