

Assessment and enhancement of SRTM and ASTER GDEM

Using Lidar Digital Elevation Mode

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*Dedicated especially to my beloved father, mother and husband.  
Thank you for their unlimited patient, loving inspiration and care May Allah bless  
them.*

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## Abstract

In the past decade, significant advances in global elevation modelling have been made with the release of the space-borne SRTM “Shuttle Radar Topography Mission” and ASTER “Advanced Spaceborne Thermal Emission and Reflection Radiometer” elevation data sets. Since a number of applications may rely solely on SRTM and/or ASTER GDEM, it is important to assess the quality of these DEMs using accurate data and precise techniques as well as finding simple but applicable approaches to improving these valuable free access DEMs. To do so, present study has focused on comprehensive methods include DEM error quantification, DEM error distribution pattern as well as DEM statistical enhancement model. After LiDAR, SRTM and ASTER GDEM data preparation, at the first step, validation of SRTM v4.1 and ASTER GDEM v.2 have been examined using LiDAR information as truth data. Various visual, empirical, and analytical approaches were used as methods. Determination the impacts of terrain characteristics on SRTM and ASTER GDEM DEMs error distribution was next stage which have been done using determination of slope and aspect effects on DEM error distribution pattern in study area. Subsequently, techniques for SRTM and ASTER GDEM enhancement have been investigated by testing varied interpolation approaches on output DEM’s quality. Regression model as a next method have been applied on interpolated DEMs for acquiring better-enhanced results. Finally, to evaluate the effects of improvements approaches on SRTM and GDEM, quantification of DEM errors was done again, and amount of RMSE and statistical parameters was calculated for enhanced SRTM and ASTER GDEM. To sum up, Results could showed us, despite last version of ASTER GDEM has finer pixel size and its validation team claims its vertical accuracy is near to 17 meter (while for our case study 28 meter), still SRTM has better quality and is more reliable than GDEM. Improved RMSE of near 15 m versus 28 meter in original data for ASTER GDEM and 10 Meter opposite 19 meter for SRTM were the results of DEM enhancement in this study.

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## CHAPTER 1

### INTRODUCTION

#### 1.1 Background

Since the 1950s, Digital Elevation Models (DEM) have been widely used in studying topography (Yang *et al.*, 2003 and Guo, 2005), geomorphology (Sauber *et al.*, 2005, Gorokhovich and Voustianiouk, 2006), vegetation cover (Kellndorfer *et al.*, 2004 and Simardet *et al.*, 2008), urban development (Gamba *et al.*, 2002), agricultural practices (Chen *et al.*, 2007) and earthquake hazards (Ganas *et al.*, 2005 and Cunningham *et al.*, 2006). Because of rapid progress in computer science and space technology, breakthroughs have been made in DEM data acquisition, storage and processing (Van Zyl, 2002). As a geospatial data framework of the basic content, DEM has played a very important role in national spatial data infrastructure and digital Earth implementation as described by Shang *et al.* and Wang *et al.* (2001). (Xiaodong Huang *et al.*, 2011).

Generally, DEM data sets can be obtained from a range of techniques, such as ground survey (Kahmen&Faig, 1988), airborne photogrammetric imagery (ASPRS, 1996), airborne laser scanning (LIDAR) (Lohr, 1998), radar altimetry (Hilton *et al.*, 2003) and interferometric synthetic aperture radar (InSAR) (Hanssen, 2001). Quite often, DEMs are constructed from data sourced from several of these methods and are thus of variable quality (Hilton *et al.*, 2003).

In the past decade, significant advances in global elevation modelling have been made with the release of the space-borne SRTM “Shuttle Radar Topography Mission” (cf. Werner, 2001 and Farr *et al.*, 2007) and ASTER “Advanced Spaceborne Thermal Emission and Reflection Radiometer”(METI/NASA, 2011) elevation data sets. The DEM data from these two space missions cover most of the populated regions of the world and are publicly available (at no cost) at spatial resolutions of 3 arc seconds for SRTM (though 1 arc second data are available to the military) and 1 arc second for ASTER. These new high-resolution data sets considerably improve the knowledge of the Earth’s surface in developing regions with poor geospatial infrastructure. However, benefit can also be gained in countries with dense forest regions which hard to surveying elevation data such as Malaysia. For such countries, SRTM and ASTER are containing useful supplementary or alternative elevation data sets (C. HIRT *et al.*, 2011).

Although these DEMs provide clear and detailed renditions of topography and terrain surfaces, these depictions can lure users into a false sense of security regarding the accuracy and precision of the data. DEM data, like other spatial data sets, are subject to error (USGS, 1997; Monmonier, 1991 and Wright, 1942). Normally potential errors, and their effect on derived data and applications based on that data, are often far from users’ consideration.

DEM errors (the departure of a given elevation from truth) have been well documented in the literature (Pike, 2002). DEM errors are generally categorized as



either systematic, blunders or random (USGS, 1997). Systematic errors result from the procedures used in the DEM generation process and follow fixed patterns that can cause bias or artifacts in the final DEM product. When the cause is known, systematic bias can be eliminated or reduced. Blunders are vertical errors associated with the data collection process and are generally identified and removed prior to release of the data. Random errors remain in the data after known blunders and systematic errors are removed. Sources of DEM errors have been described in detail, (Burrough, 1986; Heuvelink, 1998; Pike, 2002 and Wise, 1998). Error sources have been summarized as (a) data errors due to the age of data, incomplete density of observations or spatial sampling; (b) processing errors such as numerical errors in the computer, interpolation errors or classification and generalization problems; and (c) measurement errors such as positional inaccuracy (in the x and y directions), data entry faults, or observer bias (Wechsler, 2003).

Since a number of applications may rely solely on SRTM and/or ASTER DEMs, it is important to assess the quality of these data, i.e., how well does the DEM approximate the shape of the Earth's surface? Quality of elevation data is commonly expressed in terms of vertical accuracy. It can be determined using comparison data that should be based on accurate and independent methods, such as (terrestrial) topographic surveys, airborne laser scanning or photogrammetric techniques, allowing truly external and independent validation ( Wechsler SP, 2006).

A technique attracting increasing attention for its ability to provide precise and accurate ground and canopy top elevations, as well as its efficacy for validating remote sensing data sets, such as those provided by the SRTM is LiDAR remote sensing. LiDAR is an active remote sensing technique similar to radar, utilizing a focused pulse of short-wavelength (1064 nm) laser light. This short pulse (typically 5 to 10 ns at Full Width Half Maximum (FWHM)) is fired towards the Earth where it is reflected off various surfaces such as branches, leaves, and the ground before returning to the sensor. The time of flight of the laser pulse is measured and provides the range from the

instrument to the reflecting surface. The combination of this range measurement with the position and pointing of the sensor allows the laser footprint to be geolocated (Hofton *et al.*, 2000). Because the laser pulse emitted by the system is extended in time and space, and interacts with a vertically extended object, such as canopy, the return pulse is extended. The majority of existing sensors is small footprint (~1 m wide) and records the range to one or multiple ambiguous reflecting surfaces on the ground. Such systems provide a wealth of data for validation of other remote sensing data sets such as those provided by the SRTM and GDEM.

## 1.2 Statement of problem

SRTM and ASTER GDEM as open access digital elevation models (DEM) provide basic information on heights of the Earth's surface and features upon it. Existence of different uncertainties like horizontal shift, elevation offset, horizontal resolution, voids, artifacts and so on cause users faced with many ambiguous when using these open access DEMs almost knowing about their quality and relevant accuracy at various land cover including different landuse, range of relief landforms are main issues in using these free data. There is no map of showing their accuracy in individual areas like tropical countries same as Malaysia with dense forests and vegetation cover and no comprehensive study for preparing specific framework to showing different accuracy in specific land covers zones. Little is known about error propagation in open-access DEMs through the primary terrain derived attributes such as slope and aspect. In this study we have been examined the accuracy of SRTM and ASTER GDEM with LiDAR dataset as ground truth data using wide range of statistical approaches in various relief landform to investigate amount of error and relevant accuracy and the form of distribution errors in study areas.

Malaysia is a country, which is covered by dense forest in most regions. This condition is one of the problematic factors in using active remote sensor instruments in surveying ground data from the earth, cause led to removing the chance of wave penetrating through the trees. The digital elevation models (DEMs) produced by the Shuttle Radar Topographic Mission (SRTM) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) are formally DSMs, as they provide heights of surface features and includes the heights of vegetation, buildings and other surface features, and only gives elevations of the terrain in areas where there is little or no ground cover. DEM corrections and modification about removing surface effects from DSM to achieve DTM is another problem that need to be accomplished after primary assessment and before any data train analysis. (DTM usually refers the physical surface of the Earth, i.e., it gives elevations of the bare ground (terrain)). Every specific approach has its own advantages and disadvantages for example using filter for removing noises could help to smooth some high artificial area but could change other values to unreal. Using Fusion of DEM approach that reduces the errors and can improve near expected values is another approach but that is sometimes rather moderate. Knowing about simple and applicable approaches, which any one can use, is another problem that has been considered in this study.

### **1.3 Objective of study**

This research is focused on accuracy assessment of SRTM and ASTER GDEM Digital Elevation Models in Kluang area at south of Malaysi by using LiDAR dataset as a ground truth data and Geostatistical techniques as method. In fact specific objectives of this study are classified as following:

- To validate SRTM and ASTER GDEM based on LiDAR referenced points as control truth data.

- To determine the impacts of terrain characteristics on SRTM and GDEM DEMs error distribution.
- To enhance SRTM and ASTER GDEM accuracy and quality using statistical approaches.
- To quantify the effects of improvement approaches on DEMs accuracy.

#### **1.4 Scope of the study**

The scopes of the present study are to determine the quantity and quality of SRTM and ASTER GDEM as two open access sources of Digital Elevation Model using GIS and statistical techniques in three areas of variable relief: High, Median and Low relief at Kluang in State of Johor, Malaysia. Different statistical methods have been used to achieve different amounts of errors in study areas. Assessment and also consideration the effects of terrain parameters includes different types of slope and aspect classes on distribution of error in SRTM and ASTER GDEM digital elevation models is comprising next scope of this study.

By doing enhancing and modifying statistical approaches on DEMs and recognition of its restriction and possibly solving them, it is possible to get results that are more accurate from hydrological model. Finding the best method for removing the effects of ground features to improve DEMs data is another scope of this study.

Among different input parameters for finding reliable values from hydrological model, Digital Elevation Model (DEM) is one of the main important factors that its accuracy and quality can effect on preciseness of other parameters extracted from DEM like slope. Investigation of amount of DEMs error on slope accuracy is last scope of present study.

Generally, in this research ArcGIS plus SPSS used to prepare data and simulate the amounts of SRTM and GDEM errors in Kluang region as study area. Then, results will be comparing to LiDAR dataset as control point. Analyses in this procedure help to find effective parameter to generate the errors stud area.

### **1.5 Significance of the Study**

- (a) Present study can be used as a reference, which include introduction of various statistical approaches on quantifying digital elevation errors.
- (b) The results of regression equations include DEM enhancement can generalized to other places of Malaysia to improve SRTM and ASTER GDEM quality.
- (c) Findings of this analysis maybe used as resources to determine the relevance of a particular DEM datasets in varied relief terrain.

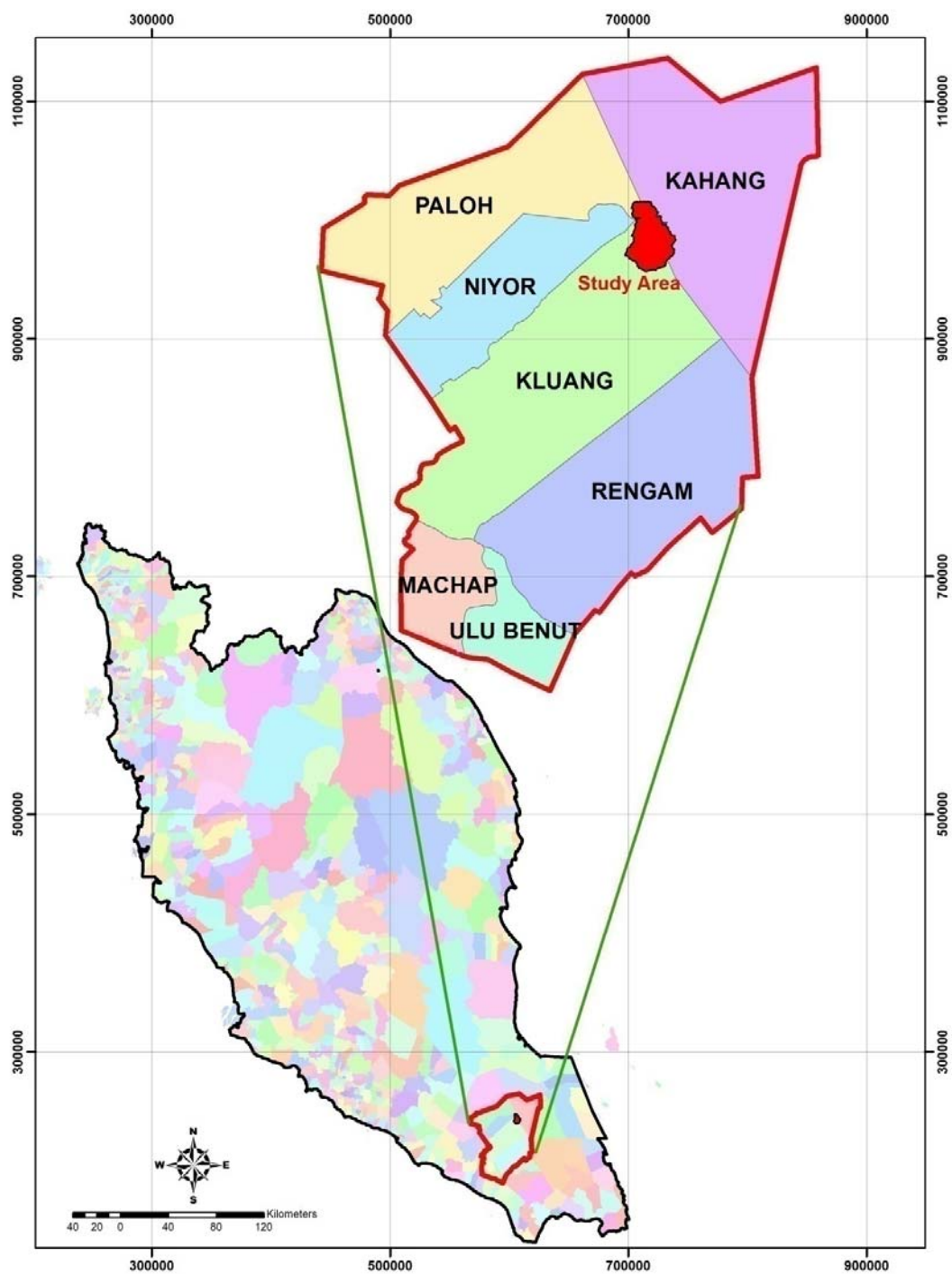
### **1.6 Site Description**

In order to evaluate the accuracy of the models over a wide range of vertical relief terrain one of the sub basins of Selai watershed was selected as study area. Basin selected is located in Kluang district in the state of Johor at the southern part of Malaysia in South-East of Asia with basin centroid occurring at latitude: 243421.7 and longitude: 606381.18. Study area is the most forest type rich area of Kluang and its area has been estimated at 31.4 KM<sup>2</sup>. Elevations range from over 8 m above sea level at northern part and ranges to under 440 m at southern part of basin. Surface drainage within the basin varies and distribute in whole of area. Figure 1 illustrates the location and hydrology of

selected basin. Table 1.1 shows the position of selected study area by X and Y at RSO KERTAU Projection system

**Table 1.1:** location of selected regions in Kluang, Johor, Malaysia

Type of site selected	Longitude (X)	Latitude (Y)
Basin	609415	247854
	603380	239509



**Figure 1.1** The location of site selected regions with three different vertical relief terrains in Kluang - Johor, Malaysia

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