Comparison of Watershed Delineation Accuracy using Open Source DEM Data in Large Area

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Abstract. The availability of watershed delineation that has been generated from DEM data is difficult to obtain and the accessibility of DEM data which are unrestricted and precise are hard to obtain in Malaysia. The aim of this study is to examine the accuracy of watershed delineation between Digital Elevation Model (DEM) from ASTER and SRTM in Johor State. In this study, free online data sources from USGS website are used to delineate watershed from ASTER and SRTM satellite imageries. The hydrological modelling tool namely ArcSWAT is utilized to delineate watersheds for both DEM datasets. Both DEM data that had been mosaiced using ERDAS imagine and their DEM is generated using ArcGIS. Watershed boundary for the whole Johor State is then being delineated by using ArcSWAT. ASTER and SRTM accuracies were verified using correlation analysis and mean center distance with data from Department of Irrigation and Drainage (DID). Study indicated that DID watershed area is correlated to ASTER and SRTM at 67.60% and 67.85%. In addition, total mean center distance for ASTER and SRTM are 148.485 and 200.200 where it shows the total mean center distance of ASTER is almost close with DID. The results from this study have successfully indicated that both ASTER and SRTM DEMs are suitable for watershed delineation for Johor State at free and reliable source.

1. Introduction
Watersheds are natural integrator of hydrological, biological and geological process such that it required integrated approach to data analysis and modelling[1]. Usually, the larger the water body, the larger the size of watershed. In hydrology studies, the demarcation and delineation of boundaries between watersheds is a challenge to estimate the planimetric area of watershed. However, only few researches about delineation of watershed have been done, particularly at large scales [2]–[5]. The growth of remote sensing (RS) and Geographic Information System (GIS) competences have stimulated and enhanced the expanded use of watershed models worldwide [6]. GIS is a suitable tool for the effective management of large and complex database and to provide a digital representation of watershed features used in hydrologic modelling. According to [6], GIS has added assurance in the accuracy of modelling by providing more everyday approach toward the watershed conditions, defining watershed features, refining the proficiency of the modelling process and eventually increasing the approximation efficiencies of hydrological modelling. In addition, DEM has been used widely in hydrological modelling due to the current development of technologies. The data is needed because to generate watershed, the information such as surface area need to be known.

Due to limitation of data provided, there are many researchers [2]–[5] finding hard to produce watershed in large area. This problem can be solved using free data from online sources such as data
from ASTER and SRTM which have been used to generate the watershed boundary. All the datasets are processed in watershed delineation software such as ArcSWAT and ArcHyd to generate the watershed. The streams that had been generated by ASTER and SRTM followed the existing river line, in order to process the stream network. The outlet in the dataset is generated for creating the watershed delineation data from ASTER and SRTM usually has been used for delineating watershed in small area but it is rarely used in wide area. Thus, this research proposed a solution to using free online data sources to produce DEM which are from ASTER and SRTM for watershed delineation in large area. It will be able to help researchers to choose the most suitable resolution size of the image to generate watershed delineation data. The watershed delineation using both ASTER and SRTM DEM had been compared using accuracy in correlation analysis and mean center in order to find the best data to represent watershed delineation.

2. Literature Review

2.1. Watershed
Watershed is an area of land that drains rain water into one location such as to stream, pond, wetland or other waterway [7]. When the rain occurs, water will travel over forest, agriculture or urban land area before entering waterway. Thus, the land and water make up a watershed system. Even though, the watershed can form into somewhat size, nevertheless commonly, the larger watershed is produced from larger body of water. Watershed will act as a filter for runoff that occurs from rain and snowmelt and given that clean water for drinking, irrigation and industry.

2.2. Digital Elevation Model (DEM)
DEM are collected by remote sensing methods or by transforming contour maps [8]. DEM is used to illustrate any topographic surface that represent in digital form. Other than that, DEM also used to refer to specifically of raster elevation or regular grid of spot height. DEM is the simplest of a topographic surface in digital form and widely used in the field but digital terrain model (DTM) is more common term for any representation of digital topographic surface. DEM offer an effective way to represent ground surface and let automated direct extraction of hydrological features, therefore it bringing benefits in terms of processing competence, cost effectiveness and accuracy assessment compared to traditional methods based on topographic maps, field survey or photographic interpretations [9].

2.3. ASTER and SRTM
The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) acquires high resolution images of earth where it has 15 to 90 square metres per pixel for images of the earth in 14 different wavelengths of the electromagnetic spectrum [10]. The users especially scientists use ASTER data to create detailed map of land surface temperature (LST), emissivity, reflectance and elevation.

Shuttle Radar Topography Mission (SRTM) is a satellite that provides Digital Elevation Models (DEMs). The SRTM gained elevation data on near-global scale to produce the most complete high-resolution topographic database of earth[11]. SRTM employed two synthetic aperture radars which are C-band system and an X-band system. The operational goal of C-RADAR was to generate connecting mapping coverage while the X-RADAR generate data along separate swaths of 5 km wide[12]. These swaths offered approximately connecting coverage at higher latitudes.

2.4. Sources of Hydrological Modelling and Watershed Delineation
In order to create hydrological modelling, DEMs and topographic data are generally apparent as providing many data. However, the data information is strictly inadequate to be obtained and most users depend on published topographic maps or DEMs that formed by government agencies such as JUPEM and DID [2]. Even though there are numerous approaches in extracting elevation data like on-site
measurement (survey), topography map or data application from government agencies, this method are conventionally deadly, time consuming and pricey for wider area. According to [13] study, in Malaysia, it is common for lacking of free and accurate available data. Due to extremely tedious work such as gathering topographic data information which can be bought from government agency, map scanning and digitizing its contour lines to extract the elevation values and later, generate DEM using elevation value, the digitizing procedure becomes unviable and produces less precise outcomes if it is applied in larger range. There are many of researches that have been done in term of producing watershed delineation [3], [14]–[16]. The watershed has been utilized for some reason, for example, it produces to know about water quality and so on. Based on previous studies by [17], the watershed delineation was conduct using ArcSWAT 2009. However, from all the previous research found, it was conducted in small focused area, therefore this research will compare the accuracy of ASTER and SRTM for watershed delineation in wide region which is the entire Johor state.

3. Methodology

The phase of work has four fundamental stages which are further explained in below subsections. The selected study area is Johor state of where it can provide large data of watershed delineation. Johor state is located from coordinates (2°49'59.844"N, 102°42'7.4736"E) upper middle to (1°21'39.078"N, 104°18'36.216"E) lower right. The area for whole state of Johor is about 19,210km² which also containing 21 rivers. The reason of the area has been chosen because there are no any previous studies of watershed delineation in large area.

![Figure 1. Study Area](image)

3.1. Stage 1- Preliminary Study

All the literatures that related to the research must be acknowledged and reviewed. Writings come from numerous sources such as, books, articles, journals, e-books and any reading sources. It is compulsory to decide the idea of the research after recognising these literatures. As the accuracies issues relating of quality digital elevation data (DEM) that could give by means of the web from open sources, for instance, data from USGS website may be validate by comparing with peak value of elevation data as the standard for additional analysis for applications. In this study, the Shuttle Radar Topography Mission (SRTM) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) were chosen to be explored and assessing the accuracies of DEM data.

3.2. Stage 2 - Data Acquisition

Data acquisition is known as data collection. The data acquisition occurred for assist the analysis after the reason of project has been decided in all relations. The data that is required in this study area are free online data which are ASTER and SRTM. Both of this data can be downloaded from Earth Explorer.
USGS website. A desired area which is Johor State. The most crucial element of GIS is finding and utilizes the appropriate data. In this study, data used was collected from several sources which are ASTER DEM, SRTM DEM, and also river and DID watershed boundary. Both of DEM data can downloaded from USGS website freely without any fees. Subsequently, the river line data, is derived from existing river map that obtained from Department of Irrigation and Drainage of Malaysia. Finally, the watershed boundary data was obtained from Department of Irrigation and Drainage of Malaysia (DID) which already been delineated using 20 metre interval contour line.

3.3. Stage 3- Data Processing
Data processing is proceeded when the data acquisition is already done. Since the SRTM DEM and ASTER is originating from various sources and has different specification, it requires to be converted into suitable projection format which is it projected into selective latitude, longitude and height system. In this way, the data processing and analysis become easier. Both of DEM data, ASTER and SRTM were included in coordinate transformation which transform from WGS84 to local coordinate such as Kertau RSO Malaya. Using ERDAS Imagine software, the ASTER and SRTM data firstly will be mosaiced into one raster image using MosaicPro tool. Afterwards, the watershed boundary for the whole Johor State for all datasets will be delineated by utilizing the ArcSWAT software.

3.4. Stage 4- Results and Data Analysis
Data analysis is the most fundamental stage in all stages since this step decided if the aim and the objective could be accomplished or not. The accuracy of both DEM data will be compared in order to make accuracy comparison of performance of the data for ASTER and SRTM. The correlation analysis will be compared between the ASTER and SRTM in term area with DID data. Method of correlation can be used in order to analyse the extent and the nature of relationships between different variables [19]. The boundary of watershed of ASTER and SRTM were compared of their location of mean center distance with DID data. The mean center distance is the average x, y and also z of all the features in the study area. It is valuable for tracking variations in the distribution or for comparing the distributions of different types of structures[20].

4. Result and Discussion
The results of the watershed delineation for ASTER and SRTM are shown in Figure 2 and Figure 3.

![Figure 2. Watershed Delineation of ASTER](image)

![Figure 3. Watershed Delineation of SRTM](image)
4.1. Correlation Analysis
The performance data for ASTER and SRTM with DID is examined using correlation analysis. The correlation analysis was involved of area that obtain from three (3) types of data used. The area that produced from ASTER and SRTM were correlated with DID area. The correlation analysis is referred to the correlation value $R^2$ which it can be calculated from correlation analysis trendline. Correlation analysis was conducted to measure the performance data from ASTER and SRTM with DID data using the area value. The correlation value $R^2$ between these area data was to determine the performance of the datasets. A good correlation value $R^2$ is when the value is near to one (1). The area of ASTER was compared with DID data and the correlation value of $R^2$ from the graph is 0.676. It is indicating that DID watershed area is correlated to ASTER watershed area at 67.60%. The SRTM also was compared with DID data and the graph show the correlation value of $R^2$ is 0.6785 where it also indicates the DID watershed area is correlated to SRTM watershed area at 67.85%. From result of the correlation value $R^2$ between ASTER and SRTM, it was nearly same. Hence, the preliminary assumption can be made where in term of area, the both of data ASTER and SRTM nearly same with the DID data.

4.2. Mean Center Distance
ASTER and SRTM have been compared in mean center distance which both DEM data was overlay with watershed from DID. Comparison between both DEM data in mean center distance where the highest distance from ASTER is 15.764 km and the lowest distance is 2.390km. As for SRTM, the highest distance is 17.900km and lowest distance is 1.353km. Most of the mean center distance from ASTER that overlay with DID data produced a smaller gap compared to SRTM that produce a bigger gap. Yet, this show that ASTER is much better in mean center distance analysis.

5. Conclusion
The research that has been made was a success with all the objectives achieved. The watersheds created a more truthful natural representation compared to the watershed from DID data. The feasibility of using online data such as ASTER and SRTM to delineate watershed were explored and the watershed delineation from ASTER and SRTM were then compared with watershed from Department of Irrigation and Drainage (DID) which had been delineated using 20 metre interval contour line. The results from this research showed that both ASTER and SRTM DEMs are suitable for watershed delineation for Johor State. In correlation analysis with DID data show the SRTM was better than ASTER where stated the correlation value $R^2$ for SRTM and DID is stronger correlation possible. While in mean center distance, the ASTER was better and gave good result compared with the SRTM.

This research can help users to generate the watershed by using free, online and comparable data sources which is able to save cost and time. Other than that, it also help the users and researchers to minimize their time and cost to collect elevation data and generate DEM in term to produce watershed boundaries [5]. It also can help users to choose which resolution they want such as 30 metres or 90 metres in term to delineate watershed either in small or wide area of interest.

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