Assessment of ASTER and SRTM Derived Digital Elevation Model for Highland Areas of Peninsular Malaysia Region

Muhamad Radzali Mispan [1], Muhammad Zamir Abdul Rasid [1,2], Nor Faiza Abd Rahman [3], Khairi Khalid[4], Siti Humaira Haron[5], Noordin Ahmad [2] .

[1,] Malaysian Agricultural Research and Development Institute (MARDI), Malaysia
[2] Faculty of Engineering, Universiti Putra Malaysia, Malaysia
[3]Faculty of Civil Engineering, Universiti Teknologi MARA, Shah Alam, Malaysia
[4] Faculty of Civil Engineering, Universiti Teknologi MARA Jengka, Pahang, Malaysia
[5] Faculty of Science and Technology, Universiti Kebangsaan Malaysia, Malaysia

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Abstract- ***Highly accurate Digital Elevation Model (DEM) is not easy to be obtained by individuals mainly because access for data is strictly limited from public use. Other factors include partial area of coverage, timely work and high cost from conducting traditional land surveying. These matters become more difficult especially in highland areas where ground surveying could not penetrate every corner of the area. With the latest technology from satellite imagery, restrictions could be resolved because free DEM data covering almost the entire Earth surface and digital copies are available for download from the internet. However, reliability of open-source DEM data still needs to be studied especially in priority areas such as highland areas with dense vegetation. This study will access on the performance of free DEM data, namely ASTER GDEM 30 meters and SRTM DEM 30 meters followed by assessment to compare these data with official contour maps generated from JUPEM at 20 meters' interval. Techniques that will be addressed include absolute accuracy assessment with differencing, profiling plots, and correlation plots as well as relative assessment by construction of watershed boundaries and river line generation with open-source GIS software. Results indicate that SRTM DEM have better elevation accuracy in terms of lower RMSE value when compared with the Reference DEM at different slope areas such as flat areas (0°) and very steep areas (more than 30°). The correlation value is less emphasized since the value obtained did not show any significant differences, indicating very close correlation between free DEM and reference DEM. Apart from that, watershed delineation as well as river line generation was very much influenced by the type of DEM being used. Overall, SRTM DEM proves much superior accuracy as compared with ASTER DEM.***

Key Words: *Watershed delineation, highland, hydrological model, accuracy assessment, open source*

1. INTRODUCTION

There are numerous types of representation of terrain surface, and one of the most commonly used technique nowadays would be by the use of Digital Elevation Models. A Digital Elevation Model (DEM) refers to the quantitative model of the Earth's terrain which is in digital form [1]. In Malaysia, precise measurement of the Earth's terrain still depends on traditional land surveying technique, which, still is the most viable option available. However, ground surveying is bound to few limiting factors, namely the size of surveying and coverage area, time consumption for conducting such work, and requirement of costly overhead investment. With latest technology in satellite imagery, it is possible for an individual to acquire topographic data in the form of DEM data. Satellite imagery for DEM generation has a tremendous advantage because it can cover a very large area, almost real time data, and can also be acquired freely from open-source platforms. Reliable DEM from open-source provider is still a hot topic and utmost importance as the starting point for conducting further analysis and simulations in environmental modelling. Studies on DEM assessment between ASTER GDEM and SRTM DEM have been done extensively throughout the world. In terms of accuracy, ASTER shows a better fit as compared to SRTM, which Rexel et.al (2014) mentioned is due to the higher resolution for ASTER. With the release of the most recent version of SRTM 30 meters DEM resolution, not much studies have been conducted to assess on the vertical accuracy, especially in the highland regions of Peninsular Malaysia, where rugged terrain and very steep slope is very well expected. This research study will evaluate how elevation from open-sourced DEM is compared with reference official contour maps, and to determine implication of DEM accuracy by using hydrological modelling simulations over GIS environment.

2. METHODOLOGY

Three sets of DEM data were compared, namely official contour maps, ASTER GDEM, and SRTM DEM. Beforehand, data preparation was conducted to get standardized format for validation. In order to conduct accuracy assessment, two different methods were conducted [2], namely absolute accuracy and relative accuracy.

2.1 Study area

This research study focuses mainly of Cameron Highlands region on the Main Range of Banjaran Titiwangsa, Malaysia which is 75 percent over 1,000 meters above sea level and extended towards the west part of Cameron Highlands (Fig- 1) on the boarders of Perak State where natural vegetation and dense forest are expected. Projected Coordinate System of Kertau RSO Malaya (Meters) were used as the reference coordinate system with Projection using Rectified Skew Orthomorphic Natural Origin.

2.2 Software as a tool

Open source GIS software, QGIS version 2.6 will be used for analysis. This version is used because of compatible software issues with the QSWAT extension that will also be used. Other plugin includes Qprof plugin for plotting profile lines and extracting pixel value, and Point Sampling Tools plugin to extract value of pixels from different digital layers.

2.3 Data Preparation

The reference contour maps, which were obtained from JUPEM, is manually cleaned and edited before converted from vector files into raster format. Since the original contour interval was at 20 meters, the raster format was created by applying conversion into 20 x 20 meter pixel resolution DEM datasets. Two open-source DEM data were obtained from USGS official website. Standardizing of projection was conducted by converting WGS 84 projection into local projection of Kertau RSO Malaya (m) projection. The nature of both raw ASTER GDEM and SRTM DEM was larger in size as compared with the reference DEM data (Fig- 1). In order to conduct correct statistical measurement, the ASTER GDEM and SRTM DEM is resized into similar study area. This was done for all DEM including reference, ASTER and SRTM data, by clipping into similar shape and corner coordinates.

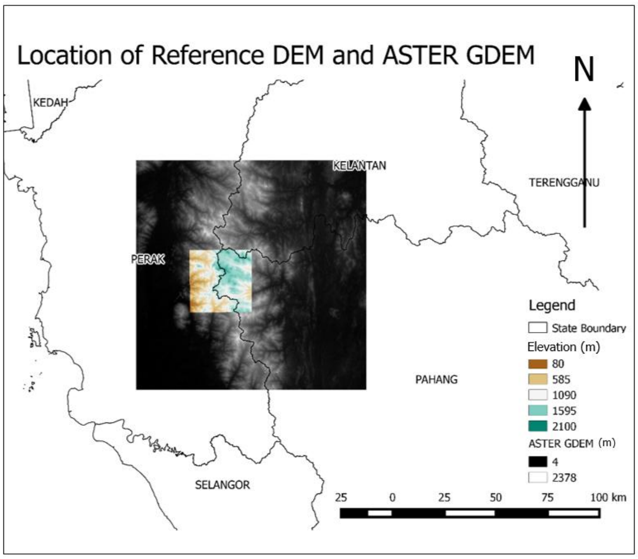


Fig -1 DEM assessment between reference contour maps and open-source DEM data study area.

2.4 Data Preparation

2.4.1 Absolute Accuracy

a) DEM *Differencing*: This was performed to derive elevation error maps by mathematical calculation of minus between Reference DEM with both ASTER and SRTM DEM. Sampling points of 6,000 points were sampled [2] to create statistics for each individual DEM's. Also, different land area was compared, which comprises of overall land area, low slope area, and steep slope area. Root Mean Square Errors (RMSE), a common measure of quantifying vertical accuracy in DEMs, was calculated for each error map.
b) *Profiling*: Horizontal profiles were created on the DEMs and compared by manual selection of different slope lands. The type of slope land consists of flat areas at 0° or water body area, West-East profile line at approximately 7.24 km, and very steep areas above 30°. The main purpose for conducting profiling was to enable visualization for outliers across the profile line between corresponding DEM's.
c) *Correlation*: This was performed to assess the level of correlation between the DEM's following on all measurement for error maps and profiling maps. Correlation and RMSE have common ground for analyzing results from studies. Correlation value is a measurement of how a particular sample data is following the line from a reference data, whereas RMSE value is a measurement of how close that sampling line is when compared with the similar reference data. For that, it can be assumed that all

DEM's have good correlation value, but in terms of RMSE and different types of terrain, the value may change accordingly.

2.4.2 Absolute Accuracy

Hydrological and geomorphological analysis was conducted and found out that SRTM is closer to represent morphometric data [5]. This was supported by [6] where SRTM elevation data were more precise in defining the basin statistics and spatial variability as compared to ASTER. The three DEMs were pre-processed to obtain watershed boundaries by using SWAT modelling algorithm. The focus is to get results of catchment boundaries and compare the total area and percentage of each HRU units by delineation of watershed, and river line generation. Additional input is also required namely soil data and land use data. In order to make comparison, all inputs for SWAT model will be similar with the exception of the three DEM input.

3. RESULTS AND DISCUSSION

3.1 Initial data

ASTER GDEM was acquired on 17th of October 2011, which is much more recent that the SRTM DEM which was acquired on 11th of February 2000. ASTER GDEM shows that the values differences are highest with both minimum and maximum DEM value at 60 meters and 2122 meters respectively. Whereas both reference DEM and SRTM DEM data value is not very much different, Reference DEM (min: 80 and max: 2100) and SRTM DEM (min: 75 and max: 2094). In terms of standard deviation, skewness and kurtosis value, the result does not differ much between DEM data sets. Paragraph comes content here. Paragraph comes content here. Paragraph comes content here.

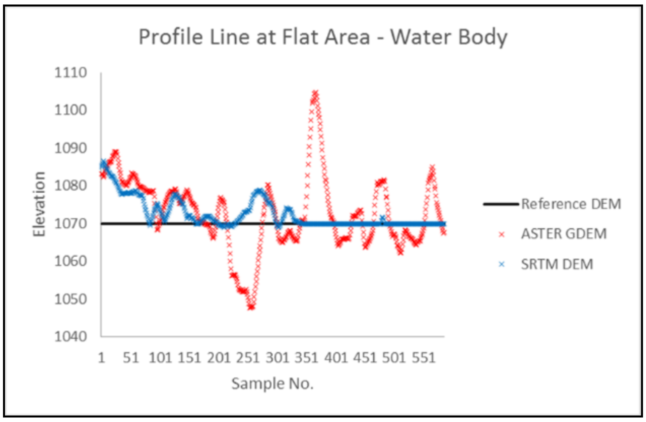
3.2 Absolute Accuracy

When conducting DEM differencing, comparison of land slope was conducted to derive error of elevation which is represented by RMSE value. In low slope area, error of elevation is lowest at ASTER and SRTM with RMSE 22.48 and 20.21 respectively. This is followed by overall land area (ASTER = 25.54 and SRTM = 24.91), and the highest error is at steep slope area (ASTER = 30.64 and SRTM = 27.32). In addition, result also shows that SRTM DEM have smaller RMSE on all land area types (low slope = 20.21, overall land = 24.91, and steep slope = 27.32) as compared with ASTER GDEM elevation error (low slope = 22.48, overall land = 25.54, and steep slope = 30.64). For ASTER GDEM, the histogram distribution is skewed on both low slope area and steep slope area. This is calculated at skewness value of -1.21 on low slope area and -0.83 on steep slope area. This value is much higher than SRTM DEM value which is almost constant at -0.02 and 0.177 respectively. Similar pattern is observed by the Kurtosis value, where ASTER GDEM have higher value on both low slope and steep slope area at 10.91 and 12.97 respectively, whereas SRTM DEM is capped at 3.617 and 3.61 respectively.

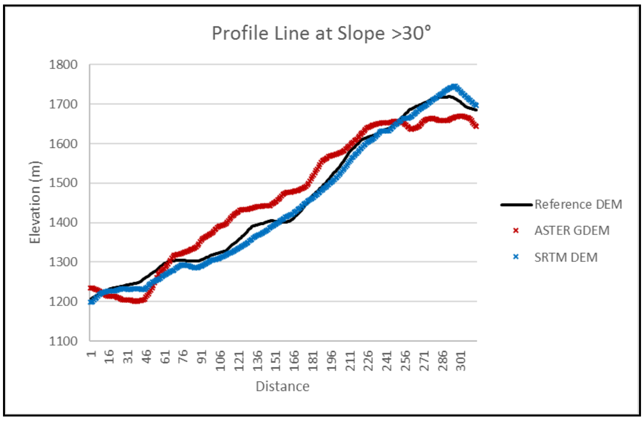
Table -1 Statistical value from DEM differencing sampling points

DEM Differencing 6,000 points	**Overall Land Area**		**Low Slope Area**		**Steep Slope Area**	
	Ref. - ASTER	Ref. - SRTM	Ref. - ASTER	Ref. - SRTM	Ref. - ASTER	Ref.- SRTM
Minimum	-188	-91	-189	-78	-376	-116
Maximum	91	84	96	60	112	76
Mean	-12.08	-16.26	-9.98	-12.7	-13.8	-15.8
Std Dev	22.5	18.881	20.15	15.74	27.35	22.3
RMSE	25.54	24.91	22.48	20.21	30.64	27.32
Skewness	-0.3351	0.177	-1.21	-0.02	-0.83	0.177
Kurtosis	5.2286	3.9508	10.91	3.617	12.97	3.61

Fig- 2 shows the profiling of DEMs. On flat surface Fig- 2(a), SRTM DEM shows a smoother elevation reading with standard deviation and RMSE at 3.79 and 4.549 respectively. However, with ASTER GDEM, it could be seen that the profile lines plotted are not flat with readings of standard deviation at 9.98 and RMSE at 10.36. This this is contributed by erroneous reading with high levels of anomalies and outliers at sampling point 251 and 370. Minimum and maximum elevation value for ASTER GDEM is recorded at 1,047.73 and 1,104.75 respectively, which is very high as compared with SRTM DEM which is recorded at minimum value of 1068.95 and maximum value of 1086.61. The occurrence of ASTER GDEM on flat area may results in misleading calculations as caused by the optical sensitivity of ASTER sensor [3]. On slope more than 30° slope Fig- 2(b), different results were also observed between DEM's. Statistically, ASTER GDEM have lower correlation value of 0.969 as compared with SRTM DEM at 0.997. This was supported by higher RMSE value for ASTER as compared with SRTM at 43.89 and 16.72 respectively.



2(a)



2(b)

Fig -2 Profile lines on (a) flat area and (b) slope of more than 30°

3.3 Relative Accuracy

Based on SWAT simulation programming, watershed delineation was able to run up to two Steps and created 7 units of boundary areas for the catchment area as shown on Table- 2. Based on the report generated, the largest difference could be observed between Subbasin 1 and 4, where difference in terms of Subbasin area coverage is observed when using ASTER DEM at 13.49% and 7.22% respectively. This is dissimilar with both reference DEM and SRTM DEM where both have almost identical Subbasin area coverage at Subbasin 1 and 4 at 15% and 5.6% respectively. This was due to the presence of different ridgeline location between ASTER and both reference DEM or SRTM DEM. Overall result shows that SRTM Subbasin generation have total area value much closer with the reference Subbasin generation.

Table -2 HRU's generated from different DEM

DEM Type	Reference		ASTER 30		SRTM 30	
	(ha)	%	(ha)	%	(ha)	%
Overall Watershed	**9,993.82**		**9,992.25**		**9,994.05**	
Subbasin 0	1,125.18	11.26	1,122.21	11.23	1,131.57	11.32
Subbasin 1	1,508.59	15.10	1,348.11	13.49	1,495.89	14.97
Subbasin 2	1,070.43	10.71	1,108.62	11.09	1,093.05	10.94
Subbasin 3	1,074.95	10.76	1,082.97	10.84	1,073.52	10.74
Subbasin 4	555.69	5.56	721.80	7.22	569.25	5.70
Subbasin 5	338.53	3.39	338.40	3.39	341.46	3.42
Subbasin 6	4,320.45	43.23	4,270.14	42.73	4,289.31	42.92

3. CONCLUSIONS

From this study, results obtained indicate that both ASTER GDEM and SRTM DEM have unique identity with regards to DEM characteristics. In terms of elevation accuracy in response to different types of land slope characteristics, SRTM shows promising results by obtaining lower RMSE value in flat terrain as well as very steep slope terrain, which was also mentioned by [4]. This proves that SRTM DEM is much likely to have similar elevation values as official contour maps from JUPEM, with much wider area of coverage. This is supported by relative assessment conducted by using hydrological modelling, where SRTM shows almost similar representation of watershed boundary and river line as the reference DEM. ASTER GDEM on the other hand, while still maintaining a good correlation between referenced DEM, does not provide good results in terms of higher errors from RMSE value. ASTER is unstable in some areas [8], which might be linked to the optical sensor characteristics that is influenced by the atmospheric condition This can be seen from higher RMSE value on rougher terrain [7]. Different values from watershed boundaries and river line creation was found when conducting hydrological simulations. Despite these shortcomings, ASTER GDEM does provide good elevation results based on lower slope areas and lower altitude zones. ASTER should be used in areas where shortcoming of SRTM [4] [8] to provide some reliable data.

It is noted that the data acquired date for ASTER GDEM was far more recent than SRTM DEM, which was in 2011 and 2000 respectively. When concerning with time factor, changes of the terrain could be effected during the time difference of more than 10 years apart. While researches and scientist are producing maps generated from digital elevation model for dynamic and good world of visualization, they may be producing data which can potentially be meaningless. This could be worsening when combining this information with decision making process, which could lead to producing unreliable data outputs and incorrect conclusions. There should be concerns by placing more emphasis towards data integrity, especially in relation to topological dataset. In turn, accurate data can be produced with better output results, thus decision making process is more reliable and correct. From this research, it is evidenced that with different types of DEM data input, variation and distinct result was generated by using a typical hydrological modelling simulation. It is hoped that with this finding and knowledge, it can assist future GIS modelers and hydrographers in their studies by reducing errors and better simulations of hydrology studies. This can be applied by introducing correctional processing procedures onto the latest ASTER GDEM datasets by removing outliers and anomalies to provide better and accurate elevation values for the earth's terrain.

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