УДК 528.831.1

ОЦЕНКА ТОЧНОСТИ ОТКРЫТЫХ ГЛОБАЛЬНЫХ ЦИФРОВЫХ МОДЕЛЕЙ РЕЛЬЕФА

Н.А. Жусупов, Т.В. Ха, Т.П. Дахал, Т.А. Ашыралиев, Бактыбек у. М.

Цифровое представление рельефа Земли называется цифровой моделью рельефа (ЦМР). Существуют различные спутниковые системы, обеспечивающие ЦМР, различное пространственное разрешение. ЦМР очень полезны для оценки стихийных бедствий, трехмерного моделирования, планирования инфраструктуры и других мероприятий по развитию. Проведена проверка надежности свободно доступных ЦМР при использовании данных для принятия решений. Три объекта из Непала, Вьетнама и Кыргызстана отобраны для оценки качества. Данные эталонной точки возвышения взяты из топографической базовой карты соответствующей области. Проведен статистический расчет для проверки достоверности данных.

Ключевые слова: цифровая модель рельефа (ЦМР); топографическая карта; высота над уровнем моря; системы координат.

РЕЛЬЕФТИН АЧЫК ААЛАМДЫК САНАРИПТИК МОДЕЛДЕРИНИН ТАКТЫГЫН БААЛОО

Н.А. Жусупов, Т.В. Ха, Т.П. Дахал, Т.А. Ашыралиев, Бактыбек у. М.

Жердин рельефинин санариптик көрүнүшү рельефтин санариптик модели деп аталат. Рельефтин санариптик моделин камсыз кылуучу ар кандай спутник системалары, ар кандай мейкиндик маалыматтары бар. Рельефтин санариптик модели жаратылыш кырсыгын баалоодо, үч өлчөмдөгү моделди түзүүдө, инфраструктураны пландоодо жана башка иш чараларда кеңири колдонулат. Бул макалада чечим кабыл алуу үчүн маалыматтарды пайдаланууда рельефтин санариптик моделинин рельефтин ачык маалыматтарынын тактыгы текшерилди. Сапатты баалоо үчүн Непал, Вьетнам жана Кыргызстандан үч объект алынган. Эталондук бийиктик чекиттин маалыматтары тиешелүү аймактын базалык топографиялык карталарынан алынды. Маалыматтардын тактыгын текшерүү үчүн статистикалык эсептөөлөр жүргүзүлдү.

Түйүндүү сөздөр: рельефтин санариптик модели; топографиялык карта; деңиз деңгээлинен бийиктиги; координаттар системалары.

QUALITY ASSESSMENT OF OPENLY ACCESSIBLE GLOBAL DEMS

N.A. Zhusupov, T.V. Ha, T.P. Dahal, T.A. Ashyraliev, Baktybek u. M.

Digital representation of the earth topography is called Digital Elevation Model (DEM). There are various satellite systems providing the DEMs with different spatial resolution. DEMs are very useful for disaster assessment, 3D modeling, infrastructure planning and other development activities. This work was carried out for testing the reliability of the freely available DEMs while using those data for decision making. Three sites of Nepal, Vietnam and Kyrgyzstan are selected for quality assessment. Reference elevation point data are taken from the topographical base map of that respective area. Statistical calculation is carried out for the testing reliability of the data.

Keywords: Digital Elevation Model (DEM); topographical map; elevation; coordinate systems.

Introduction. Graphical representation of geographic setting is called a map. It is very important for height representation in mapping during base map preparation. Digital representation of elevation generally raster based (or cell based) with the single elevation representing the entire area of the cell. Digital elevation models (DEMs) are arrays of regularly spaced elevation values referenced

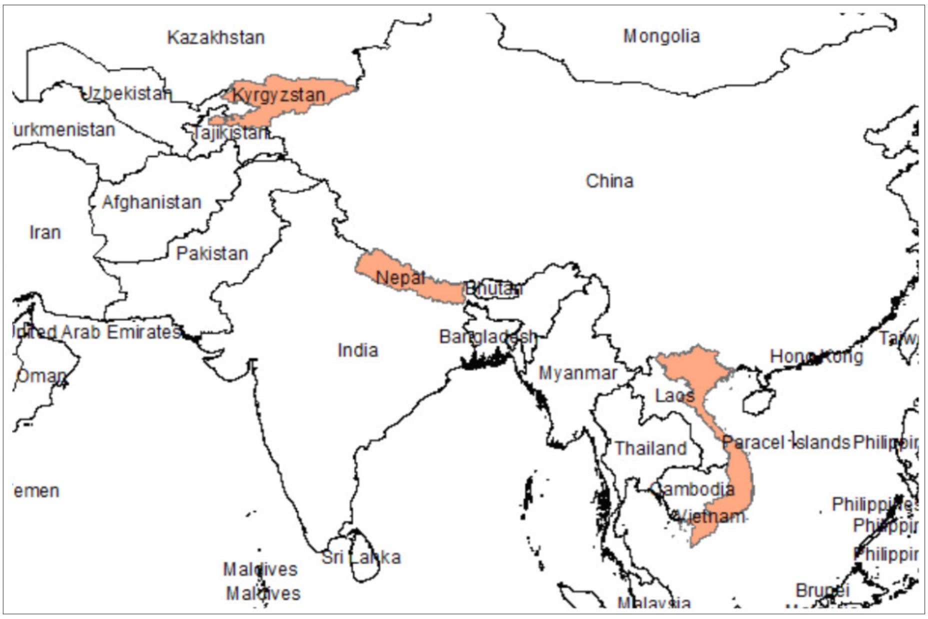

Figure 1 – Study Area (Nepal, Vietnam and Kyrgyzstan)

horizontally either to a Universal Transverse Mercator (UTM) projection or to a geographic coordinate system (USGS, 2019).

DEM can be used for various application areas. Some of the major application areas of DEM are;

- Pre-feasibility study of possible hydropower site selection
- Urban planning and 3D city modeling
- Flood modeling (Flood simulation)
- Landslide Hazard zonation and simulation modeling
- Topographic base map preparation
- Land use zoning and planning
- Simulation of possible solar energy collection from building tops
- Creation of relief maps

There are various techniques for DEM generation. The major sources for DEM preparation are photogrammetry using stereo photographs. DEM can be accurately generated by field survey method using Total Station and GPS. Nowadays Laser Scanning and interferometry are widely used for creating fast and reliable DEM. The DEM creation for large area is difficult task and it is tedious process by using field-based technique. There are number of freely available DEMs generated by using optical as well as SAR data. The quality of the freely available data should be assessed before used. This work mainly focused on the quality assessment of the freely available DEMs based on the topographical based maps.

Study area. The study area of this project work is chosen in three different countries of the world. Those three countries are Nepal, Vietnam and Kyrgyzstan. Study coverage of three parts of those countries has different topography. The study area selected in Nepal, Kyrgyzstan and Vietnam is hilly mostly hilly topography including vegetation and urban area. The location map of the study area is shown as below;

The area selected for sample data in Nepal is Kavrepalanchok, similarly Thai Nguyen of Vietnam and Sokuluk area of Kyrgyzstan. DEMs of those areas are included in Annex-I.

Method. To carry out the quality assessment of the openly accessible global DEMs can be shown in various steps as flow diagram. The flow diagram has two parts one is searching and downloading openly accessible DEMs. Other part is collection of reference data for validation points using existing base maps of the country.

DEMs used:

A. Satellite Derived Datasets

1. ALOS PALSAR RTC HR- 12.5m spatial resolution
2. ASTER GDEM V2-30 m Spatial resolution

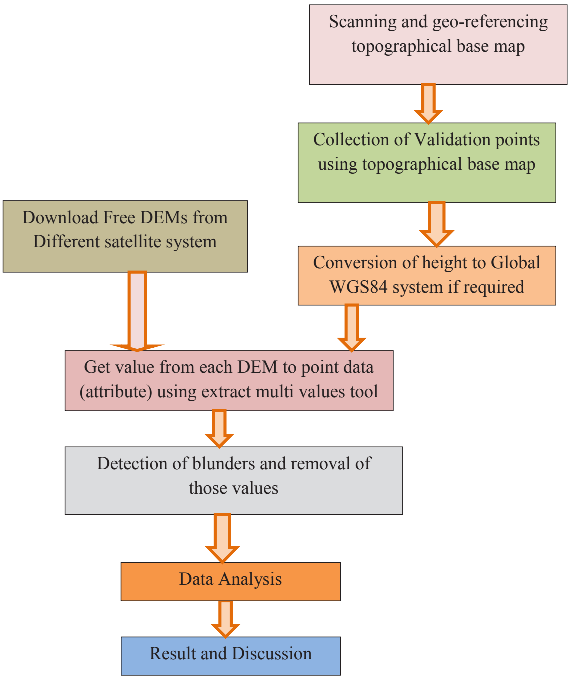

Figure 2 – Methodology

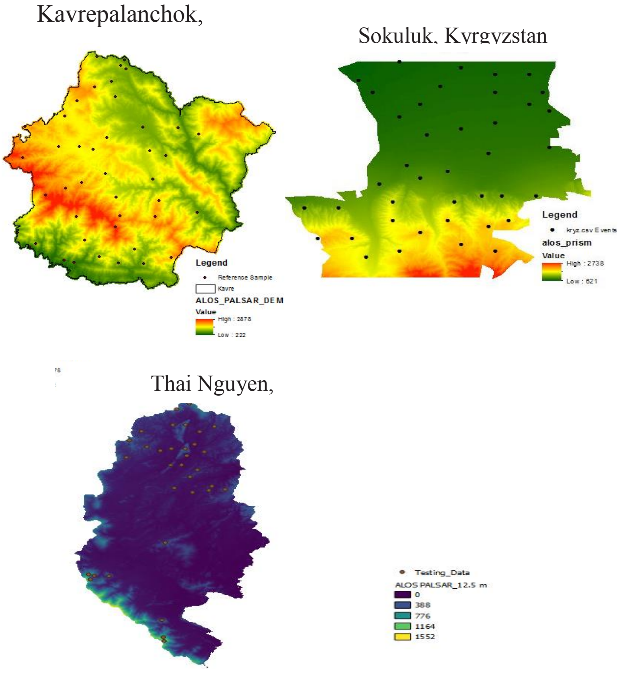

Figure 3 – Study area sample DEMs

3. SRTM 30m DEM – 30m Spatial resolution
4. ALOS PRISM (AW3D30) – 30m Spatial Resolution
5. CartoDEM V3 R1 – 30m Spatial Resolution.
6. TamDEMX- 90m Spatial Resolution

B. Topographical Maps

1. Topographical map of scale 1:25000 (Nepal & Kyrgyzstan)
2. Topographical map of scale 1:50000 (Vietnam)

It is noted that not all DEMs are available for three countries, so we used only selected and available DEMs that are freely available to the country of interest. For example, CartoDEM V3 R1 DEM is not available for the Vietnam and Kyrgyzstan region, so it is excluded. In case of problem in ALOS PALSAR RTC HR DEM, it is excluded in case of Kyrgyzstan.

Validation Data. This study is used reference data points collected from the topographical map sheet published by their Surveying and Mapping agencies of the respective Countries. The height of the reference samples is taken from maps as control point and spot heights. Those map heights are orthometric height. Specially, there are 30 reference data points collected for the study area of Vietnam digitization of points using 1:50000 scale topographical map; 44 points are chosen for Nepal digitized using 1:25000 scale topographical map, while 40 points is collected for Kyrgyzstan using 1:25000 scale topographical map. The topography of selected countries is hilly area having variation in topography including vegetation and urban area.

The sample data (DEM) and reference points collected from three countries are shown as below;

Data Analysis. Data analysis is carried out in GIS environment using reference points as vector data and DEMs as Raster data. The extraction of height from DEMs to reference data is carried out using Extract Multi Values to Points tool available in ArcGIS 10x. DEMs freely available are not in same vertical datum so was used 'Online geoid calculations using the GeoidEval utility' for calculation of Geoid undulation for conversion of orthometric height to Ellipsoid height (WGS84). The statistical calculation for the mean deviation and RMSE calculation is done using MS-Excel.

The statistical calculations:

a. RMSE Value Calculation:

Table 1 – RMSE Value of Open Source DEMs

RMSE Value (in Meter)			
DEM	NEPAL	VIETNAM	KYRGYZSTAN
ALOS PALSAR RTC HR	6.4	12.16	-
CartoDEM V3 R1	11.4	No data	No data
SRTM DEM	6.6	12.22	6.58
ASTER GDEM V2	12.5	8.71	7.60
ALOS PRISM (AW3D30)	5.9	11.33	6.41
TANDEM-X 90m	11.3	-	6.81

The table shows that in case of Nepal among six DEMs the least RMSE value is 5.9 for ALOS PRISM (AW3D30) 30m spatial resolution, similarly among four Data sets for Vietnam and Kyrgyzstan shows that the least RMSE value for ASTER GDEM V2 30m and ALOS PRISM 30m. In case of Kyrgyzstan the RMSE value difference is less compared to Nepal and Vietnam. Based on the RMSE value as well as correction made for ASTER GDEM V2 and SRTM DEM shows ALOS PRISM (AW3D30) is more reliable DEM. The RMSE Plot of the tabular data in bar chart is shown below;

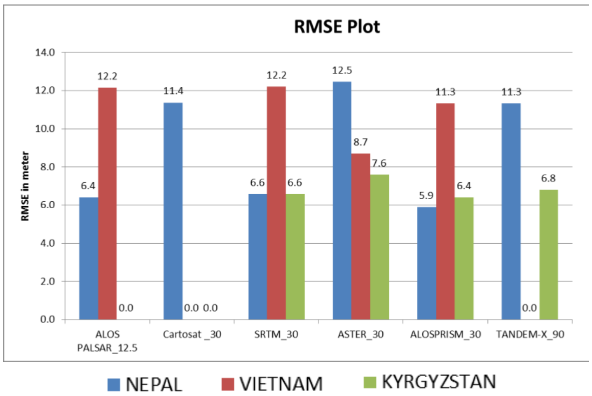

Figure 4 – RMSE Chart

b. Mean Deviation calculation:

The mean deviation values for study area of three countries are mentioned in following table;

Table 2 – Mean Deviation of Open Source DEMs

MEAN DEVIATION (in Meter)			
DEM	NEPAL	VIETNAM	KYRGYZSTAN
ALOS PALSAR RTC HR	5.64	9.30	-
CartoDEM V3 R1	5.79	No data	No data
SRTM DEM	5.26	10.17	6.58
ASTER GDEM V2	10.22	6.18	6.19
ALOS PRISM (AW3D30)	5.28	9.46	4.21
TANDEM-X 90m	8.03	-	4.62

Form the mean deviation table the least value of deviation for Nepal, Vietnam and Kyrgyzstan is 5.26, 6.18 and 4.21 for SRTM DEM 30m, ASTER GDEM V2 30m and ALOS PRISM (AW3D30) 30m respectively. The bar chart of the mean deviation is as below;

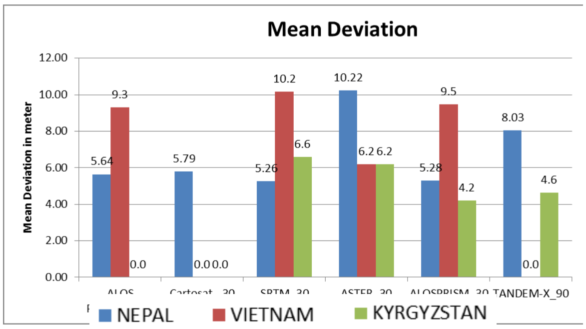

Figure 5 – Mean Deviation Chart

c. Standard Deviation calculation:

The standard deviation calculation for those study areas based on the reference data are mentioned in following table.

Standard deviation table shows that the least amount of standard deviation for Nepal, Vietnam and Kyrgyzstan is 5.81for ALOS PALSAR RTC HR (12.5m), 9.08 for ASTER GDEM V2 (30m) and 5.15 for ASTER GDEM V2 (30m) respectively. The data shows that the deviation value in Kyrgyzstan is less deviated compared to Nepal and Vietnam. The bar diagram of the table is plotted below;

Table 3 – Standard Deviation of Open Source DEMs

STANDARD DEVIATION (in Meter)			
DEM	NEPAL	VIETNAM	KYRGYZSTAN
ALOS PALSAR RTC HR	5.81	13.08	-
CartoDEM V3 R1	7.59	No data	No data
SRTM DEM	6.13	14.72	5.52
ASTER GDEM V2	7.85	9.08	5.15
ALOS PRISM (AW3D30)	6.58	15.52	5.97
TANDEM-X 90m	8.22	0	5.74

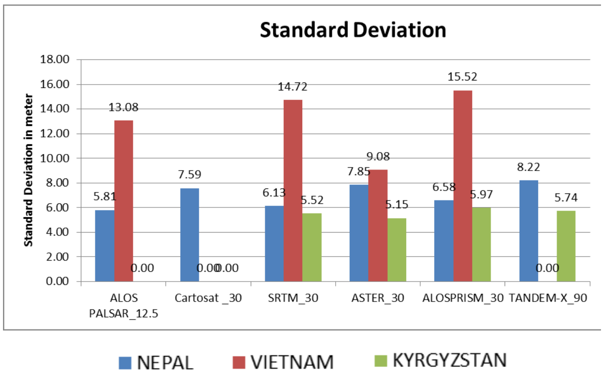

Figure 6 – Standard Deviation Chart

Conclusion. There are various satellite systems which provide openly accessible global DEMs generated by various technologies. The most common open source DEMs used in this project work are ASTER GDEM V2 (30m), SRTM DEM(30m), TanDEM-X 90m, ALOS PALSAR RTC HR (12.5m), ALOS PRISM (AW3D30) (30m) and CartoDEM V3 R1 (30m). CartoDEM V3 R1 (30m) DEM is available for only India and neighboring countries. Remaining DEMs are available globally. The validation samples are taken from the topographical base map of scale 1:25000 and 1:50000 (Vietnam). The height provided in different DEMs are in different vertical datum those heights are converted to ellipsoidal height using Online geoid calculations using the GeoidEval utility with geoid undulation for each reference sample points based on latitude and longitude.

The extraction of DEM height to the point is carried out using ArcGIS10x and further statistical calculation are carried out using MS-Excel. The RMSE calculation shows that the ALOS PRISM (AW3D30) DEM 30m spatial resolution having RMSE value 5.6m is the best DEM among the six DEMs for study area of Nepal. RMSE value of the ALOS PALSAR RTC HR having 6.4 seems to be less accurate than the ALOS PRISM (AW3D30) DEM having 12.5m spatial resolution. In case of reference data in Vietnam ASTER GDEM V2 DEMs having RMSE value 8.71 seems better compared to other three DEMs. ALOS PRISM (AW3D30) DEM having RMSE value 6.41 found to be better for Kyrgyzstan. This study is expected to provide the public users as a reference so that they can choose the “best” openly accessible DEMs for their own project.

Due to the limitation of time of the project secondary data are used for validation of DEMs. The topography of the selected area is hilly area having topographical variation including vegetation coverage. It is recommended to use primary field data for validation of the DEMs is better compared to the use of validation points from topographical map of scale 1:25000 & 1:50000.

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