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AW3D30 and SRTM30 Digital Elevation Models* –Comparison around coastal islands in Gyeongsangnam-do, South Korea–

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AW3D30 DEM과 SRTM30 DEM의 정확도 비교* –경상남도 연안도서를 중심으로–

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ABSTRACT

DEM(Digital Elevation Model) being fundamental data in geospatial domain is produced from different data and using various methods. As they are derived their precision varies and altering derivative in application. In this work, we compare two widely used DEMs namely(Advanced Land Observing Satellite World 3D 30m and Shuttle Radar Topography Mission Global 30m) around coastal islands in Gyeongsangnam-do, South Korea. First statistics of each DEM were calculated and later overlapped in Landsat image for visual comparison of areas below and above zero-meter elevation. As a result, it was found that DEMs were highly correlated with each other and had similar statistics. Besides having few high differences in hilly land area, they were able to represent the coastal lines. It has also been noted that they have many negative values and should carefully select study area covering full watershed in coastal regions to avoid negative elevation even after filling the sinks.

KEYWORDS : DEM, AW3D30, SRTM30, Coastal Islands, Gyeongsangnam-do

요 약

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수치표고모델(DEM, Digital Elevation Model)은 지형공간 영역의 기본 데이터로서, 다양한 데이터로부터 다양한 방법으로 만들어진다. 수치표고모델이 파생됨에 따라, 적용 분야에서의 그 정밀도 또한 다양하게 변화한다. 본 연구에서는, 대한민국 경상남도 연안의 섬 주변에서 광범위하게 사용되는 있는 두 가지 DEM, 즉 육역관측기술위성 월드 3D 30m(ALOS World 3D 30m) 및 셔틀 레이더지형미션 글로벌 30m(SRTM Global 30m)를 비교하였다. 우선 DEM의 첫 번째 통계를 계산한 다음, 해발표고 0을 기준으로 높고 낮은 지역을 시각적으로 비교하기 위하여 Landsat 이미지에 중첩하였다. 연구 결과, DEM은 서로 높은 상관관계가 있으며, 유사한 통계를 가지고 있음을 알 수 있었다. 그리고 구릉지에서는 높은 차이가 거의 없었을 뿐만 아니라, 해안선을 나타낼 수 있었다. 또한 DEM은 많은 음의 값을 가지고 있다는 점이 확인되었으며, 싱크를 채운 후에도 표고가 음으로 측정되는 것을 방지하기 위해, 해안 지역 전체를 포함하는 연구 지역을 신중하게 선택해야 할 것으로 보인다.

주요어 : 수치표고모델, AW3D30, SRTM30, 연안 도서, 경상남도

Introduction

DEM(Digital Elevation Model) is one the fundamental data in geospatial domain. It is digital representation of the earth' s topography. Nowadays, DEMs are derived from contours from topographic maps, spot heights from field surveying using theodolite, total station or real time kinematic GPS(Global Positioning System), LiDAR(Light Detection and Ranging) scanning, matching stereo images. DEM are widely used in various studies in the field of hydrology(Acharya *et al.*, 2016), landslide modeling(Hong *et al.*, 2018; Acharya *et al.*, 2017a; Yang *et al.*, 2016), transportation planning(Yang *et al.*, 2014; Acharya *et al.*, 2017b) and so on. Their demand has been grown and applications are thus being done from local to global level.

One of the major limitation of the DEM data is that they have various precision. They change according to the source of data, method used(Schumann *et al.*, 2008). Change in precision of DEM also have chances to add errors and leading to alteration of derived results(Goulden *et al.*, 2016; Oksanen and Sarjakoski, 2005; Gyasi-Agyei *et al.*, 1995). Hence, it is necessary to access the robustness and their likelihood from each other for potential use in various applications.

In this work, we aimed to work on the application of DEM in coastal areas where there are many islands. We focus on the comparison of two well-known satellite derived DEMs: AW3D30(Advanced Land Observing Satellite World 3D 30m) (Tadono *et al.*, 2014) and SRTM30 (Shuttle Radar Topography Mission Global 30m)(Farr *et al.*, 2007) around coastal islands in Gyeongsangnam-do, South Korea. To see the similarity, we calculated statistics of each resolution DEM and visually interpreted area below and above zero-meter level.

Introduction

1. Study Area

The study area selected to compare the two DEMs is from Gyeongsangnam-do,

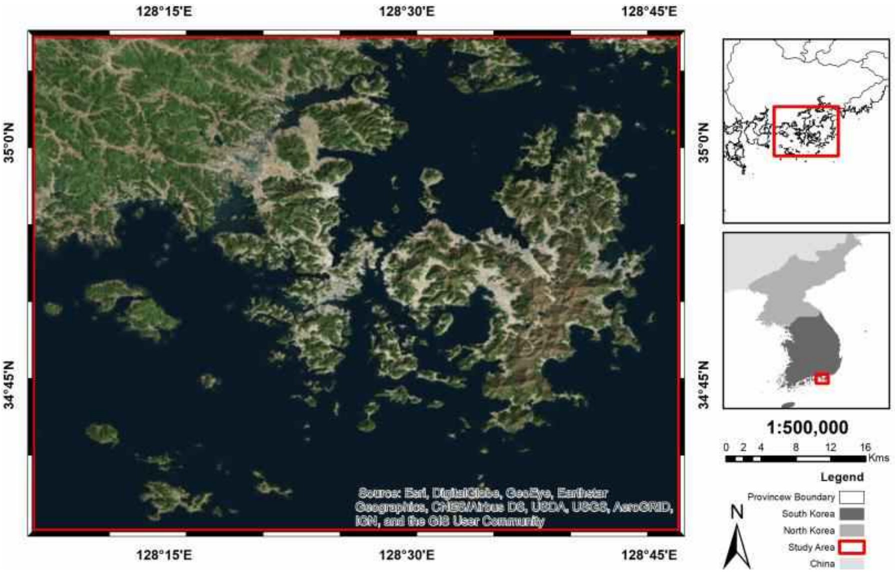

FIGURE 1. The location map with DEM in meters of test area (Chuncheon, South Korea)

South Korea. A total area of 3443.36 sq. km. was selected that lies between 34° 35′ 22.21″ N to 35° 05′ 57.33″ N and 128° 6′ 41.07″ E to 128° 46′ 40.07″ E. The location map of the study area in natural color satellite image is shown in Figure 1. The coastal area has many islands where mostly hilly forest are farmlands. Geoje island is the largest and most famous island in the study area.

2. Data

The study used two clipped portions of satellites derived DEMs for comparison. First one is AW3D30 downloaded from its website (http://www.eorc.jaxa.jp/ALOS/en/aw3d30/data/index.htm). The Japan Aerospace Exploration Agency released "ALOS World 3D - 30m (AW3D30)", the global DSM (Digital Surface Model) dataset with a horizontal resolution of approx. 30-meter mesh (1×1 arcsecond), free of charge in May 2015. The 2.1 version (Takaku and Tadono, 2017) has been updated in April 2018 with void-filled 14,535 DSM tiles within 60 deg. of N/S and partly over 60 deg. of N. And the second one is SRTM30 version 3 extracted from OpenTopography portal (Krishnan *et al.*, 2011). The NASA version 3.0 product is void-filled using elevation data from other sources. Its coverage includes Africa, Europe, North America, South America, Asia, and Australia. Both data were resampled at a resolution of 30 meters for uniformity in WGS 1984 coordinate system. More details and evaluation of DEMs in hilly areas (Acharya *et al.*, 2018).

3. Methodology

First of all, both the DEMs were resampled using resample tool of ArcGIS with processing extent larger than study area for uniform pixels. This will help in comparison with similar location pixels.

After that, nine statistical parameters: minimum, first quartile, median, mean, third quartile, maximum, standard deviation, skewness, and kurtosis were calculated for DEM. In any dataset, the smallest value is lowest whereas the largest one is maximum. Mean is defined as the average and is computed as the sum of all the observed outcomes from the sample divided by the total number of events as follow:

$$Mean(\overline{x}) = \frac{1}{n}\sum_{i-1}^{n} x \quad (1)$$

Median is a number in statistics that tells you where the middle of a data set is. After arranging the numbers in ascending number, median is calculated as:

$$Median = \left[\frac{n+1}{2}\right] th \quad (2)$$

Where n is the number of items in the dataset and th means the nth number in the ascending data set.

Before defining the first and third quartile, one should understand lower and upper half of the dataset. The lower half of a data set is the set of all values that are to the left of the median value when the data has been put into increasing order. In same way, upper half is on the right of the median. And now, the first and third quartile are the median of the lower and upper half dataset. This means, 25% of the items lies below first quartile and 25% of the items lies above third quartile.

Standard deviation is a measure that is used to quantify the amount of variation or dispersion of a set of data values. A low standard deviation indicates that the data points tend to be close to the mean (also called the expected value) of the set, while a high standard deviation indicates that the data points are spread out over a wider range of values. It is calculated as:

$$Standard\,deviation\,(\sigma) = \sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2/n} \quad (3)$$

where is an item and is the mean, and n is the total number of items in the dataset.

Skewness is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the center point. Kurtosis is a measure of whether the data are heavy-tailed or light-tailed relative to a normal distribution. That is, data sets with high kurtosis tend to have heavy tails, or outliers. Data sets with low kurtosis tend to have light tails, or lack of outliers. A uniform distribution would be the extreme case. For a univariate data, the formulae for skewness and kurtosis are given as follow:

$$Skewness = \frac{\sum_{i=1}^{n}(x_i - \overline{x})^3/n}{\sigma^3} \quad (4)$$

$$Kurtosis = \frac{\sum_{i=1}^{n}(x_i - \overline{x})^4/n}{\sigma^4} \quad (5)$$

Where is an item and is the mean, σ is standard deviation and n is the total number of items in the dataset.

First parameters for the original DEM were calculated and later they were filled

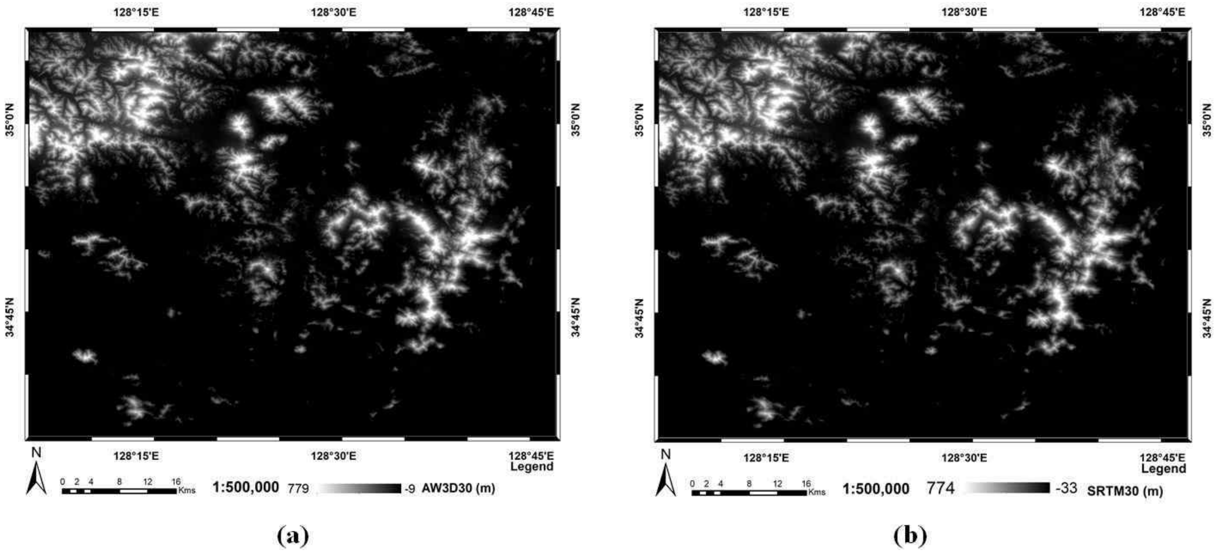

FIGURE 2. DEM of the study area: (a) ADW3D30 and (b) SRTM30

to calculate same parameters to see the change. These statistics are very common in comparative studies in geospatial field (Acharya *et al*., 2018; Lee and Acharya, 2017; Dawod and Al-Ghamdi, 2017).

And for the coastal and islands, areal coverage of below and above zero elevation was calculated. The comparison was done based on overlaying two coastal boundaries and their aerial coverage. The statistical calculations were derived using R package whereas all spatial analysis and graphics were produced in ArcGIS.

Result and Discussion

After the download and resampling of the DEM into same projection, statistics for both raster images were calculated. Figure 1 shows the raster dataset whereas the Table 1 shows the statistics of the DEMs.

From both figure 1 and Table 1, we can see that both data has negative elevation. SRTM30 have larger −33m compared to AW3D30 i.e., −9m. The maximum value is also varying but rest of them are quite similar in statistics. There is a difference of one meter in standard deviation between two DEMs before and after fill. In figure 3, the box plot shows that the negative values in SRTM30 are higher in number compared to the other dataset. Similarly, we can also see the histogram and correlation to be 0.999 almost identical.

To see the difference between two DEMs, simple subtraction was done i.e., ADW3D30 - SRTM30. Figure 3c show the result with difference ranging from −91 to 139m. From the figure, it is clear that sea areas agree in the DEM whereas land areas do not. And most of the positive lies in north-western region whereas as negative ones in south eastern regions, exactly opposite of each other. This could be a major drawback of scanning view and angle of the sensors while capturing the data.

To check the effect of filling the DEMS, we performed fill analysis using ArcGIS

TABLE 1. Statistics of the DEMs in meters before and after filling

Statistics	DEM (m)		Filled DEM (m)	
	AW3D30	SRTM30	AW3D30	SRTM30
Minimum	−9	−33	0	−5
1st Quartile	0	0	0	0
Median	0	0	0	0
Mean	46.79	46.28	46.81	46.30
3rd Quartile	58	57	58	57
Maximum	779	774	779	774
Standard Deviation	88.186	87.152	88.183	87.164
Skewness	2.313	2.329	2.314	2.328
Kurtosis	5.518	5.623	5.518	5.622

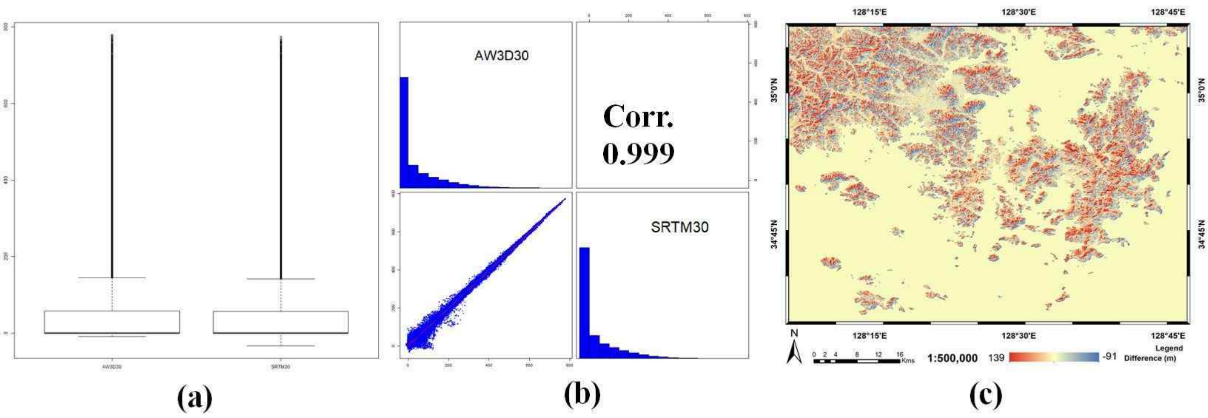

FIGURE 3. (a) Boxplot of DEMs and (b) Histogram and correlation plot of DEMs, and (c) Difference between DEMs

and found that ADW3D30 was able to fill all the sinks whereas SRTM30 still have few remaining at the top coastal area (Figure 4). It seems that the cut watershed in coastal areas could be a problem in filling. Hence, while selecting data for coastal area, the watershed should be as much as possible without cutting it.

In coastal areas, one of the most important features is coastal lines. Hence, in this work, we choose to check how the DEM represents the coastal lines and how much they cover in area. First, we use satellite image from Landsat to compare the coastal boundaries. As shown in Figure 4, both DEMs shows error in elevation values thus leading to confusing coastal boundary and small polygons. But, in case of islands, both were able to represent island boundaries well. A small doubt of the time/season of data acquisition could be reason in small disagreement in boundaries.

For the next step of analysis, we converted the above and below zero level area into land and sea and thus try to calculate the area of each for comparison. As in Table 2, both DEMs represents almost similar amount of area and small difference could be due to the calculation of small pixels in boundary areas of study area.

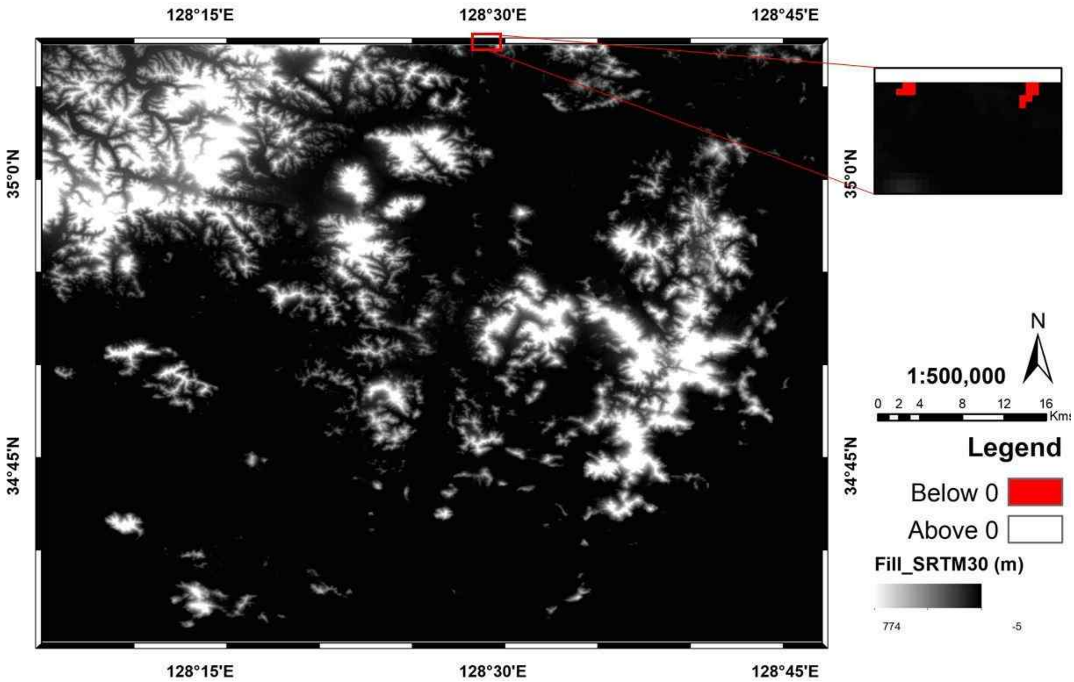

FIGURE 4. SRTM30 DEM after Fill analysis. The zoom box shows the negative elevation after fill

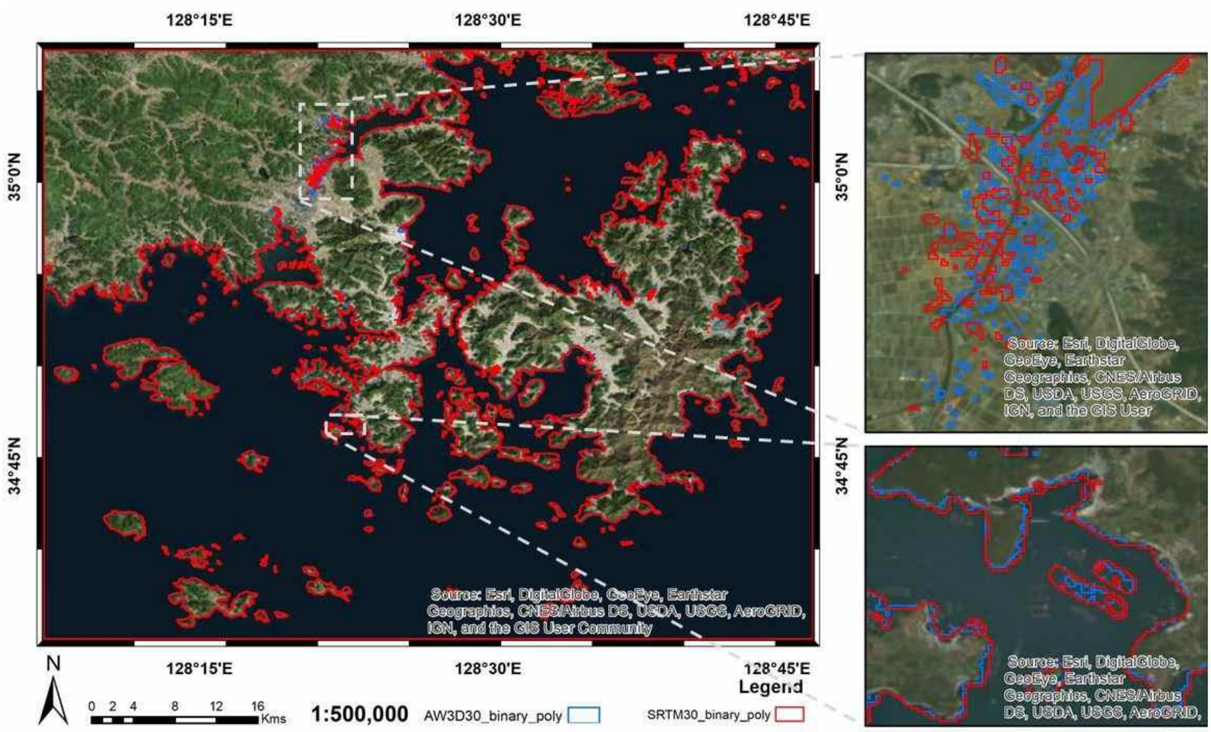

FIGURE 5. Coastal boundaries based on elevation in DEM with zoomed areas for comparison of DEMs.

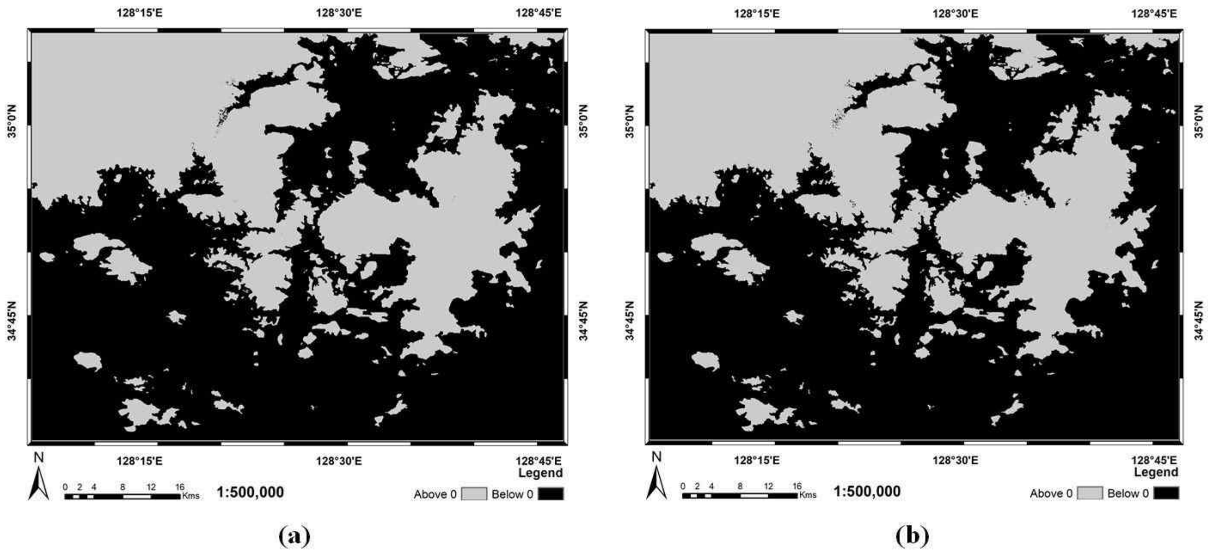

FIGURE 6. Area below and above zero meters: (a) ADW3D30 and (b) SRTM30

TABLE 2. Pixels and area below and above zero meters

DEM	Pixels		Area (sq. km.)	
	Below Zero	Above Zero	Below Zero	Above Zero
AW3D30	2697408	1716192	1341.63	2109.28
SRTM30	2697038	1716562	1341.75	2109

Conclusion

In this study, comparative analysis of two widely used satellite derived DEMs was performed based on statistics and overlapping to Landsat image. It has been found that both DEMs have negative elevation and were highly correlated to each other. However, SRTM30 had more in the study area and due to poor selection to cover watershed area fill also left negative elevation in it. The difference found between them could be result of acquisition view and angle of senor or temporal variability.

DEM is primary geospatial data in various analysis but varies with data and method used. It is recommended to compare multiple source and if possible validate for suitable use. Although, this study shows how the DEM can be compared and understand the difference. It is recommended that for further work, to use national DEM or LiDAR DEM to compare and verify the accuracy of global DEMs. Furthermore, investigation of watershed and hydrological applications would also help to evaluate the DEMs. KAGIS

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