ASSESSMENT OF DEMS PRODUCED BY MEDIUM RESOLUTION OPTICAL SENSORS CONSIDERING LAND COVER CLASSES

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ABSTRACT

A digital elevation model (DEM) presents immense data proving three dimensional terrain structure of any part of the Earth. DEMs are obtained by two main methods in space-borne remote sensing as stereoscopy using optical or radar imagery and interferometric synthetic aperture radar (InSAR) technology. In fact, the primary product of space-borne remote sensing techniques is a digital surface model (DSM) that contains points located on the top of ground objects. By removing these points that do not belong to the bare ground, the DEM is obtained. In optical imagery, DSMs are generated based on stereo matching using ground control points and co-located clear tie points at stereo image-pair with high correlation. In this case, correlation comes into prominence and affects the success of DSM acquired by stereoscopy. This investigation aims to assess the quality of DEMs produced by medium resolution spatial data derived from optical imagery depending upon the effect of correlation in stereoscopy correspondingly the land cover types. Towards this purpose, land cover classes have been generated such as open, forest, built-up, road network and rocky regions, DSM-DEM conversion was applied by optimal filtering methods and DEM accuracies have been achieved separately. The analyses were realized using actual ASTER GDEM Version 2 with 30m original grid spacing in Zonguldak, Turkey including rugged topography and suitable land cover classes. For the verification, a reference DEM derived from 1/1000 scaled aerial photos was employed.

1. INTRODUCTION

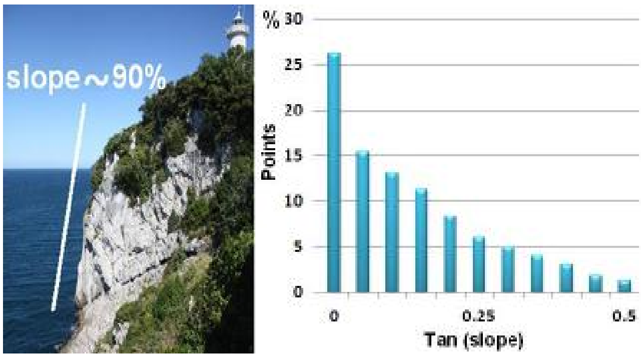
As known, it is impossible to describe the terrain of Earth by the horizontal components and the height information is required for three dimensional (3D) representation. To lead 3D data about the surface of bare ground, several terrestrial (ground surveying) and celestial (aerial and space-borne) digital elevation model (DEM) generation techniques have been developed. Each of them has advantages and disadvantages against others. For the selection of optimal technique on any application, two main factors as coverage and accuracy are come into prominence. For instance, the advantage of space-borne generation techniques is large land coverage up to global scale which cannot be offered by any terrestrial or aerial techniques. On the other hand, expected accuracy is lower (0.5m-20m considering USGS standards).

In the study, the accuracy assessment of classified DEM obtained by medium resolution spatial data was targeted. Correspondingly, ASTER Global DEM (GDEM) of test field Fener, Turkey was obtained. By contrast with its name, ASTER GDEM is a digital surface model (DSM) including entire objects on the ground such as vegetation, forest and human made formations because just DSMs can be obtained by aerial and spatial data (Li et al., 2005). From this point of view, at the implementation first the DSM-DEM conversion was performed by filtering and the accuracies of DEM classes were defined applying a group of evaluation analysis. At the application, present maps achieved from aerial photos by stereoscopy were used for generation of land classes and the DEM derived from same data was used for the verification of accuracies.

2. TEST SITE

Fener, Turkey

Fener (means lighthouse in Turkish) is a part of Zonguldak city which is at the West Black Sea region of Turkey. It covers approximately 1km×1km area with a rolling topography including various types of terrain formations. The altitude reaches up to 150m and vertical cliffs are available on the coastal zone. Figure 1 shows an example from the coastal zone of test field and the frequency distribution of terrain slope.

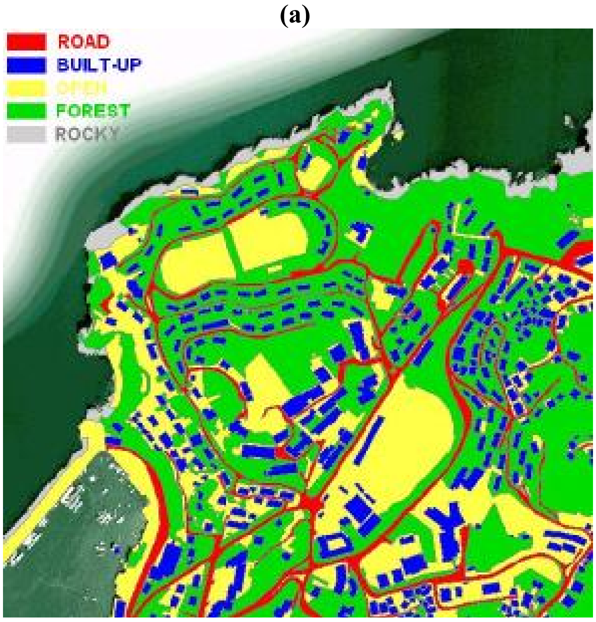


(a) **(b)**

Figure 1, An example from vertical cliffs (a) and the frequency distribution of terrain slope (b)

We thought that Fener is a suitable test field for DEM classification and accuracy analysis on different layers. Accordingly, it was classified into five layers as road, built-up, open, forest and rocky before the evaluation. Figure 2 indicates the orthophoto of test field and the layers.

(a)



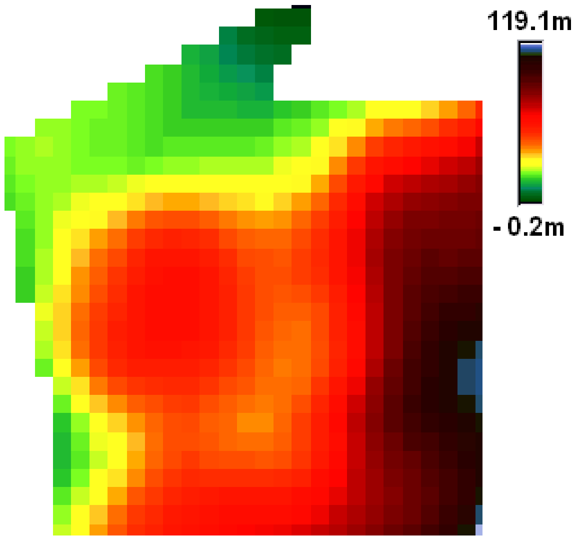
(b)

Figure 2, Orthophoto of test site Fener (a) and layers (b)

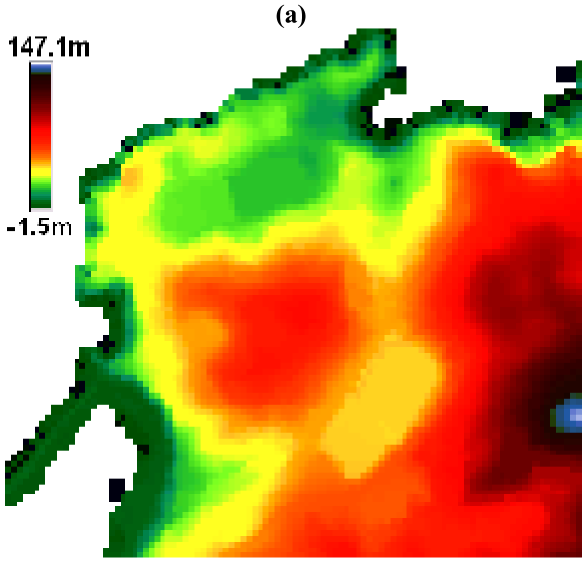
3. DATA SETS

One of the space-borne DEM generation methods is optical stereoscopy using stereo images. With the advantage of stereo viewing capability, a global DEM was generated using ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) (JPL, 2011) data and it was allowed to the scientific usage in 29 June 2009. This DEM has 1 arcsecond (~30m) posting interval, approximately 20m vertical and 30m horizontal accuracy with 95% confidence. It is the largest DEM that covers almost entire planet surpassing Shuttle Radar Topograhy Mission's (SRTM) (Koch and Heipke 2001, Sefercik 2009) coverage of 56°S to 60°N. Detailed evaluation about ASTER GDEM can be seen in Sefercik, 2012.

The reference DEM of test field was produced by 1/1000 scaled aerial photos from a photogrammetric flight project of Zonguldak Municipality in August 2005. It has 10cm-1m accuracy and 10m grid spacing. Figure 3 shows the ASTER GDEM and the reference DEM of Fener.



(a)



(b)

Figure 3, ASTER GDEM (a) and the reference DEM (b)

4. EVALUATION OF CLASSIFIED DEM

In this research, entire DEM evaluation process was applied using system BLUH (Bundle Block Adjustment Leibniz University Hannover) which was developed by Dr. Karsten Jacobsen.

As known, DEM is often used as a general term for DSMs and digital terrain models (DTMs) that's why the producers may entitle the product as ASTER GDEM. But in reality it is a DSM because only DSMs can be generated from air-borne and space-borne remote sensing data. It is the three dimensional digital cartographic representation of Earth surface and distinctly from DEM, it includes vegetation, forest, hydrological structures and entire man-made formations. From this point of view, before starting accuracy assessment, the first step was the conversion of DSM into DEM. In this study, program RASCOR was used for DSM-DEM conversion. Considering rolling topography and the object heights on the test field, we preferred Linear Prediction algorithm due to the fact that it is a more robust technique (Passini et. al, 2002) and the ground objects such as buildings, vegetation, forest etc. were eliminated. Owing to the filtering, 13.43% of details were eliminated and the gaps consisted. Finally, these gaps were filled by optimum interpolation method and DSMs were converted into DEMs.

Before accuracy assessment, another important step is elimination of horizontal shifts between evaluated DEM and the reference because of not precise known datum of national coordinate systems. Therefore, the shifts between ASTER GDEM and reference DEM were determined by adjustment with automatic shifting. The adjusted shifts and the root mean square (RMS) 'Z' values before and after shifting process can be seen in Table 1.

Ref. DEM	DEM	RMSZ Before Shift (m)	SHIFT	Final RMSZ (m)
ZDAK 1000	ASTER GDEM	8.61	X= 9.07 Y= 16.61	7.98

Table 1, Results of shifting

After shifting, the accuracy analyses were performed separately for each layer. At the analyses, the root mean square of height differences (RMSZ) between classified DEMs and reference DEM were calculated by adjustment using program DEMANAL. RMSZ is depending upon the terrain inclination that's why the accuracy has to be described by a constant value plus a constant value multiplied with the tangent of the terrain inclination (tan(α)). The maximum accepted height difference 'ΔZ' was defined as '50m' and the maximum accepted tangent slope was defined as '10' (~85º) at the application and the points which exceed these limits were excepted and marked as 'Not Accepted Point' (NAP). Table 2 shows the accuracies of ASTER GDEM classes. The following Figure 4 illustrates the DEM classes (left) and NAPs (right). Normally, NAPs are indicated as white spots at the analyze figures. As can be seen from the Figure 4, no NAP is detected at the analyses.

Ref. DEM	ASTER GDEM Class	Coverage (%)	NAP	Accuracy (m)
ZDAK 1000	Road	7.99	0.00	4.38+0.00× tan (α)
	Built-up	11.98	0.00	5.23+60.73×tan (α)
	Open	23.00	0.00	6.21+46.93×tan (α)
	Forest	59.55	0.00	7.15+20.68×tan (α)
	Rocky	2.63	0.00	18.05+18.59×tan (α)
	General	100	0.00	7.39+17.67× tan (α)

Table 2, Accuracies of DEM classes

As a summary of Table 2;

- As expected, in road, built-up and open areas, GDEM has better accuracy in comparison with forest and rocky regions.
- By the advantage of near infrared spectral band used for the stereo combinations, the accuracy of forest area is close with road, built-up and open areas.
- Because of damaged surface, the accuracy is quite low in rocky areas.

- General accuracy of ASTER GDEM is nearly 7.5m. This corresponds 1/50000-1/100000 scaled map accuracy considering USGS map production standards.

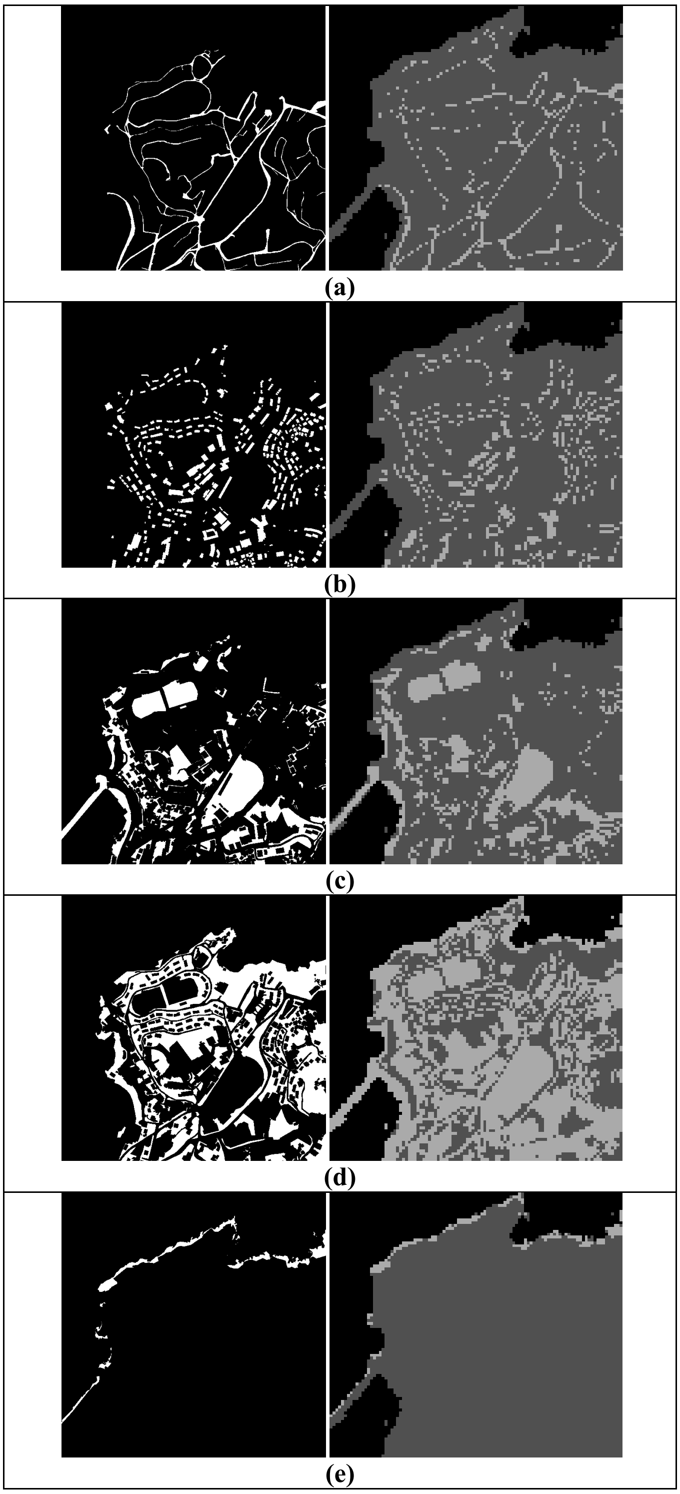


Figure 4, DEM classes as road (a), built-up (b), open (c), forest (d) and rocky (e) areas and NAPs

5. CONCLUSION

In the paper, the accuracy assessment of classified DEMs derived from medium resolution optical sensors' data was aimed.

For this purpose, a suitable test field was stated from Turkey including various terrain formations and ASTER GDEM of this area was obtained.

Five separate layers as road, built-up, open, forest and rocky were defined for the accuracy analysis using a present map achieved from aerial photos.

Before accuracy assessment, DSM-DEM conversion by filtering and shifting were employed and ASTER GDEM was converted into a real DEM.

At the accuracy analysis, a DEM derived from large scale photogrammetry was used as reference for verification.

According to the results of accuracy analysis; in road, built-up and open areas, GDEM has better accuracy in comparison with forest and rocky regions.

The forest area is close with them. Because of damaged surface, the accuracy is quite low in rocky areas. By the advantage of near infrared spectral band used for the stereo combinations, the accuracy of forest area is close with road, built-up and open areas. And because of damaged surface, the accuracy is quite low in rocky areas.

General accuracy of ASTER GDEM is nearly 7.5m. This corresponds 1/50000-1/100000 scaled map accuracy considering USGS map production standards.

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REFERENCES

Li, Z., Zhu, Q., Gold, C., 2005. Digital Terrain Modelling: Principles and Methodology. CRC Press, ISBN: 0-415-32462-9, Florida, USA.

Koch, A., Heipke, C., 2001. Quality Assessment of Digital Surface Models Derived From the Shuttle Radar Topography Mission (SRTM). IEEE 2001 International Geoscience and Remote Sensing Symposium, University of New South Wales, 9-13th July, Sydney (Australia).

Passini, R., and Jacobsen, B.D., 2002. Filtering of digital elevation models, Proceedings of the ASPRS 2002 Annual Convention, 19–26 April, Washington DC (American Society for Photogrammetry and Remote Sensing, Bethesda, Maryland).

Sefercik, U., Alkan, M., 2009. Advanced analysis of differences between C and X bands using SRTM data for mountainous topography. Journal of the Indian Society of Remote Sensing, Springer, ISSN: 0255-660X (Print) 0974-3006 (Online), Press: DOI: 10.1007/s12524-009-0044-4, Pages: 335-349.

Sefercik, U., 2012. Performance Estimation of Aster Global DEM Depending upon the Terrain Inclination. Journal of the Indian Society of Remote Sensing, Springer, DOI: 10.1007/s12524-012-0202-y.

JPL (Jet Propulsion Laboratory), California Institute of Technology, 2011. NASA web site, ASTER Mission, last visit September, 543 2011, http://asterweb.jpl.nasa.gov/mission.asp.