Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
Annals of DAAAM International

# THE EVALUATION OF DIFFERENT TYPES OF DIGITAL ELEVETION MODELS FOR GEOMORPHOLOGICAL APPLICATIONS IN MOUNTAIN AREAS

**TOROK - OANCE, M[arcel] F[rancisc]; ARDELEAN, F[lorina] - M[inodora]; ONACA, A[lexandru] L[ucian]; VOICULESCU, M[ircea] & URDEA, P[etru]**

***Abstract:*** *Digital elevation models (DEMs) are the most powerful methods of representing relief. Because there are many types of DEMs regarding the data sources, we have tried to identify the most suitable DEMs for the terrain analysis in mountain areas. We evaluated DEMs obtained from different data sources and several interpolation methods. We used both visual analysis and geostatistical analysis to assess the accuracy of the altitude data and the quality of the surface morphology representation. The geostatistical analysis showed that there are no significant differences between the DEMs regarding the altitude values excepting the ASTER and SRTM DEM but the analysis of the topographic profiles and the comparison with field data demonstrated that the best DEMs are the model generated by Topo to Raster function and the SPOT DEM.*
***Key words:*** *DEM, geostatistic analysis, interpolation, geomorphological applications*

## 1. INTRODUCTION

The use of DEMs has increased in the last years in everyday life and in many research fields. The digital analysis of the relief, including the geomorphological mapping and the geomorphological modelling, offers reliable results only if the models used in analysis have an appropriate quality regarding both the altitude data and the accuracy of the represented landforms.

Many studies debated the DEMs quality and the interpolation methods used in DEM generation (Mitas and Mitášová, 1999, Carlisle, 2005) even in relation to landform types (Chaplot et all, 2006) but unfortunately there are less similar studies for mountain areas. In mountainous areas, errors appear on DEMs derived from topographical maps due to lack of altitude values in areas with steep slopes and horizontal surfaces, saddles and peaks. They also appear on DEMs derived from remote sensing data in areas with steep gradients and high terrain roughness. Therefore, we tried to identify the most suitable model for the automatic classification of the landforms in the alpine area of the Southern Carpathians.

In this approach we used different methods to assess the accuracy of DEMs in mountain areas. We evaluated DEMs derived both from topographic maps and from remote sensing data. First, we compared the DEMs using geostatistical analysis of the altitude data. Second, we developed new methods for the estimation of the accuracy of the surface morphology representation. These methods are: the comparison between topographical profiles extracted from DEMs for different types of landforms, the comparison between the contour lines extracted from DEMs and the contour lines from the topographical maps and the comparison between the hydrographical network derived from DEMs and the one from topographical maps. We also used altitudinal data collected by topographic survey. The study area is situated in the Ţarcu Mountains (fig.1), and is representative for the relief of the alpine level of the Southern Carpathians (Romania). The altitudes range between 1035 – 2090 m. The major elements of the study area's landscape are represented by the planation surfaces and glacial and periglacial landforms (glacial cirques and valleys, talus cones and scree slopes).

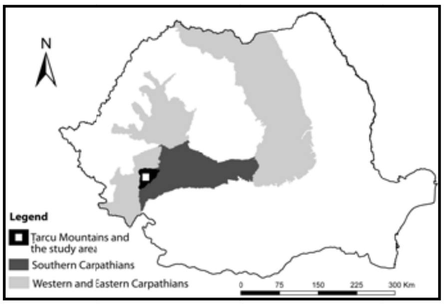

Fig. 1. Location of the study area

Further studies may include more accurate models, like LiDAR DEMs, but in present there are no such data for the Romanian Carpathians.

## 2. MATERIALS AND METHODS

The data used in the analysis are: topographic maps at scale 1:25000, 30 m resolution SPOT-HRS DEM, 30 m resolution ASTER DEM, 90 m resolution SRTM DEM and elevation data collected in the study area with a Leica TPS 400 total station.

In order to produce DEMs derived from topographical maps we made the data transfer of the analogue topographical maps in digital form. First, we scanned the maps at 400 dpi resolution and we georeferenced them in Stereo 1970 national reference system using ArcGIS 9.2 software. The RMS error is between 0.4 - 1.1m. We have digitized the contour lines and the elevation points from the digital topographic maps. All the resulting data were stored in a geodatabase. The DEMs generation was done in Idrisi Andes and ArcGIS 9.2 software using the interpolation of the altitudinal data. The following interpolation algorithms were used: Kriging, IDW (inverse distance weighted), Natural Neighbour, Spline, TIN and Topo To Raster. All the DEMs we obtained were stored as raster files at10 m resolutions.

The second types of analyzed DEMs were the models derived from remote-sensed data: SPOT, ASTER and SRTM. We extracted from these models only the area which overlapped the study area. In order to compare them with DEMs derived from topographical maps and with field data we resampled these models in the same coordinate system, Stereo 1970.

We used both visual analysis and geostatistical analysis to assess the accuracy of the altitude data and the quality of the surface morphology representation. The accuracy assessment of the altitude data was made by geostatatistical methods. We compared the heights values recorded in each DEM by statistical tests (GraphPad InStat v3.05 software) for different samples: 500 randomly selected points for entire study area and 100 points for the heights along the topographical profiles. Finally we compared the heights values of the DEMs with field data: 425 altitudinal values collected by topographic survey.

## 3. DATA ANALYSIS AND DISCUSSION

The analysis of the summary statistics of all nine types of DEMs indicated that there are no important differences between the statistical parameters. The variation of the mean altitude value is only 2.6 m but the variations of the minimum and maximum values are higher. We noticed that for the DEMs derived from remote-sensed data, because of the specific method of height data aquisition with active sensors, the values recorded higher variations. As a rule, both mean and maximum values are lower than the real altitude, because the sensor recorded the average altitude for a small area (pixel). Contrary, in areas covered by forest, situated in the lower part of the study area, the values are higher then the real ones because the sensor recorded the heights of the objects and not the height of the topographic surface. The highest difference between the real altitudes and the DEM was noticed for the SRTM DEM: 68 m for the minimum value and -41 m for the maximum altitude.

Another method to compare the DEMs was the statistical tests (GraphPad software). We used samples of 500 random extracted elevation points for each DEM. We have generated the points using a stratified random function (Idrisi software) which assures a better selection of the samples regarding the spatial distribution. All the 9 array data had normal distribution and to compare the data we applied the paired t-test. The result demonstrated that the samples did not differ significantly ($p>0.05$) except the data from SRTM DEM ($p<0.001$). Although the statistical analysis showed that most of the models are similar regarding the altitudes, the visual analysis of the DEMs, including 3D visualisation, showed significant differences both in the relief representation and on the longitudinal and transversal profile lines.

The next step was the statistical analysis of the heights values from the profile lines. Easy Profiler 9.2, a multi-layers and multi-profile tool for ArcGIS, allowed the extraction of the topographical profiles from DEMs, both in graphic and numeric form (100 data for each line). The topographic profiles were created along different landforms: plateaus, glacial cirques and valleys. We used both summary statistics and the same paired t-test to compare the profiles. The profiles created from the DEMs generated from topographical maps and from SPOT-HRS DEM are similar regarding the altitudes ($p>0.05$) but the profiles created from SRTM and ASTER DEMs differ significantly ($p<0.001$).

Visual analysis of the profiles showed also that for DEMs obtained from Natural Neighbour, Topo To Raster, TIN and Kriging interpolation methods and for SPOT-HRS, the profile line is very smooth and close to the real landform, while for DEMs obtained from IDW and Spline interpolation methods and SRTM and ASTER DEMS the profiles show more irregular lines, with many thresholds in slope angle (fig.2).

To assess the accuracy of the DEMs concerning the real altitudes we compared the values of 425 altitude points collected by topographic survey and the heights values extracted from the same location from DEMs. The statistical test demonstrated that the DEM generated by Topo To Raster function fitted the field data the best (Pearson correlation coefficient $r = 0.9738$, $p < 0.001$).

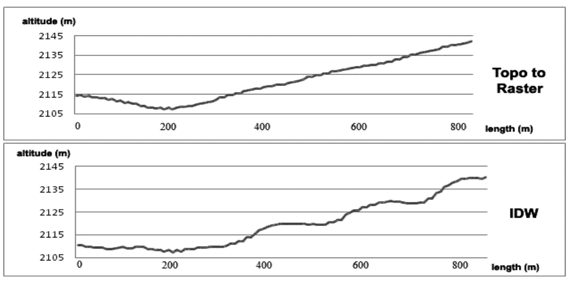

Fig. 2. Differences in profile lines extracted from two types of DEMs

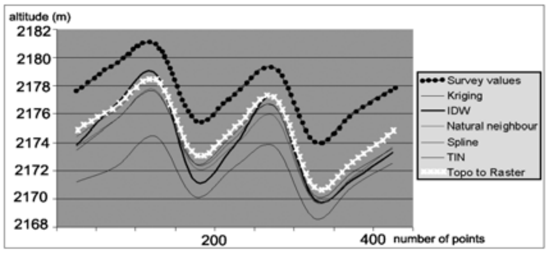

Fig. 3. Comparison between heights data from DEMs and survey data

We noted also a strong correlation between the measured values and the heights values recorded on SPOT DEM, but only in the areas with no forest.

The comparison between the contour lines extracted from DEMs and the contour lines from the topographical maps as well as the comparison between the hydrographical networks derived from DEMs and the one from topographical maps are complementary methods developed for the evaluation of the accuracy regarding the surface morphology representation. The DEM generated by Topo To Raster function and the SPOT HRS DEM are the most accurate DEMs for relief analysis.

## 4. CONCLUSIONS

The geostatistical analysis of the altitude values from the DEMs and the statistical and visual analysis of the topographic profiles extracted from the DEMs, for some relief forms, demonstrate that between models are not significant differences excepting the SRTM and ASTER DEM, which are not suitable for detailed geomorphological analysis. The IDW and Spline interpolation methods generated also models with errors in profile lines (interpolation artefacts).

The comparison between the real altitudes and DEMs argued that the best model is the DEM generated by Topo To Raster function. The SPOT-HRS DEM is also a good choice but only in the areas with no forest. The assessment of the contour lines and the hydrographical networks extracted from DEMs emphasized that the best DEMs for geomorphological applications are the DEM generated by Topo To Raster function and the SPOT-HRS DEM.

Further studies may include the assessment of the morphometrical values derived from DEMs and also more accurate models, like LiDAR DEMs, but in present there are no such data for the Romanian Carpathians.

## 5. ACKNOWLEDGEMENTS

This work was supported by CNMP, project number PNII– GEOMORF 32-140/2008 and by CNCSIS–UEFISCSU, project number PNII–IDEI 1075/2009.

## 6. REFERENCES

Carlisle, B. H. (2005), Modelling the Spatial Distribution of DEM Error. *Transactions in GIS*, 9: 521–540.

Chaplot et all, (2006), Accuracy of interpolation techniques for the derivation of digital elevation models in relation to landform types and data density, *Geomorphology*, 77 (1-2), pp. 126-141

Hengl, T., Reuter, I., H., (2009), *Geomorphometry, Concepts, Software, Applications,* Elsevier, Amsterdam

Mitas, L., Mitášová, H., (1999), Spatial interpolation. In: *Geographical Information Systems: Principles, Techniques, Management and Applications*, vol. 1, Longley, P., Goodchild, M.F., Maguire, D.J., Rhind, D.W. (Eds.), Wiley, pp. 481–492

Wilson, J., P., Gallant, J., C., (2000), *Terrain Analysis - Principles and Applications*, John Wiley and Sons inc., 9780471321880, New York