COMPARISON OF DIFFERENT DEM DERIVED LANDFORM ANALYSIS (CASE OF KAKHETI, GEORGIA)

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ABSTRACT

Topography plays an unraveled role in many biophysical processes and phenomena. The main problem, however, is that measurement, representation, and characterization of such a vast and continuous feature are very challenging. The accuracy of Digital Elevation Models (DEMs) has a direct influence on the results of the further landform analysis. In this paper, we use existing approaches of landform analysis with the use of global DEMs in the large-scale regional study. A detailed comparison was made between landforms derived from SRTM 1 Arc-Second (30 m) and ASTER GDEM v3 (30 m) to quantitively and qualitatively assess their accuracy over the Kakheti Region, Georgia which is characterized by the complex terrain and then to compare it with a reference model derived from laser scanning (LiDAR-5m). The approach was based on landform analysis developed by Weiss and updated by Jenness for the GIS interface. The landform analysis process involves combining primary terrain attributes (slope, aspect, curvature, topographic wetness index) to secondary attributes (Topographic Position Index). 10 different landforms were derived from each DEM. Approximately 400 ground control points (GCPs) were used for comparison. The results demonstrated that SRTM DEM is characterized by better elevation accuracy. According to the percentage metric of landform analysis, SRTM DEM has better results especially in the case of plains. Only a few areas especially mountain tops and high ridges where ASTER GDEM V3 had a small advantage. We have demonstrated that this comparison is one among wide research results which can be an answer for which DEM is more suitable for landform analysis.

Keywords: DEM, landforms, ASTER, SRTM, Georgia

INTRODUCTION

It is generally accepted that many physical and biological processes acting on the landscape are highly correlated with topographic position: a hilltop, valley bottom, exposed ridge, flat plain, upper or lower slope, and so on. If we want to understand the relief of the Earth's surface (which is highly complex) we need to simplify and subdivide it into landforms. Of course, many landforms can be delineated manually using photo-interpretation to assess their form, size, scale, adjacency, surface roughness, hydrological and contextual position but there is always a problem with the boundary of the landform Landforms in this narrower sense are areal objects on a DEM, and in general, they have the third dimension — they are volumetric [1].

In order to understand the topography and its role in environmental processes and phenomena, there needs to be a technique for measuring, representing, and characterizing it reliably. Measurement, representation, and characterization of such a vast and continuous feature are very challenging. There are many ways of modeling terrain. Digital modeling involves a virtual realization of terrain using computers [2]. The outcome of any model is dependent upon the original data that is used for the modeling. In digital terrain analysis, the digitally stored elevation and other topographic features are used to derive other terrain attributes.

There are currently many global and freely-available DEMs They have different resolutions (from 25x25 m to 1x1 km) and vertical accuracies (from 5-7 m to 300 m). The most common and affordable of them are ASTER GDEM and SRTM. The ASTER GDEM covers land surfaces between 83°N and 83°S and is comprised of 22,702 tiles. This model is distributed as georeferenced tagged image file format (GeoTIFF) files. The data have a resolution at 1 arc-second (approximately 30 m) grid and referenced to the 1984 World Geodetic System (WGS84)/1996 Earth Gravitational Model (EGM96) geoid. Although the ASTER GDEM v. 002 is a better model than ASTER GDEM v. 001, users have to know that the data still may contain anomalies and artifacts [3]. SRTM 1 Arc-Second Global elevation data offers worldwide coverage of void filled data at 1 arc-second (30 m) resolution and provides the open distribution of this high-resolution global data set [3]. It is interesting to note that in studies such as Digital Terrain Morphomety and other similar studies, which one should be preferred when selecting DEM. Both have some limitations. Despite the global coverage and uniformity of the study they do not provide information on bare-earth elevation as they measure the elevation of the highest objects above the ground (i.e. SRTM3 DEM was generated by C-band radar interferometry, ASTER was developed by collecting in-track stereo using nadir and aft looking near-infrared cameras, AW3D30 was generated by the panchromatic remote-sensing instrument for stereo mapping, etc.). This situation limits the use of global DEMs in geomorphological modeling, especially in large-scale local-regional studies [4]. A few researchers have addressed the problem of DEM accuracy. They share a number of interesting insights. For example, in assessing the vertical accuracy of DEMs it was found that only a single tile where GDEM might be better than SRTM, in a very flat area; overall the quality of the 3" SRTM data set exceeds the 1" GDEM. A comparison with SRTM might provide a fast and accurate assessment of GDEM quality [5]. The same is confirmed by the following paper. Uncertainties of soil erosion modeling. The results indicate that the SRTM DEM performs better than the ASTER and the CARTOSAT DEMs in assessing the accuracy [6]. In the case of ASTER GDEM, the values of slope steepness are overestimated, and it can be negative effects on the modeling of erosion processes [7]. In addition, Water bodies pose a particular problem for the ASTER GDEM [5]. Studies give us an idea of the individual attributes, but what happens when it comes directly to the landform In contrast to local terrain parameters, which may be calculated using a moving 3x3 grid cells window (slope, aspect, curvatures), complex terrain parameters establish a broader spatial relationship by identifying the particular area of the terrain, which is directly linked to a location through process interaction [8]. Ideally, LiDAR elevation data should be used in terrain analysis for its high spatial resolution and accuracy characteristics. However, it is not available in all regions.

Despite much improvement of ASTER DEM, at a local scale, it is still important to perform a case-by-case verification of the precision of GDEM data for understanding the potential and limitations in its application in a specific region. There remains a need for future assessments. The purpose of this study is to evaluate the quality of SRTM DEM and ASTER GDEM version 2 in terms of landform analysis in the Kakheti region, Georgia using ground control points from local Lidar DEM (5m).

METHODS AND MATERIALS

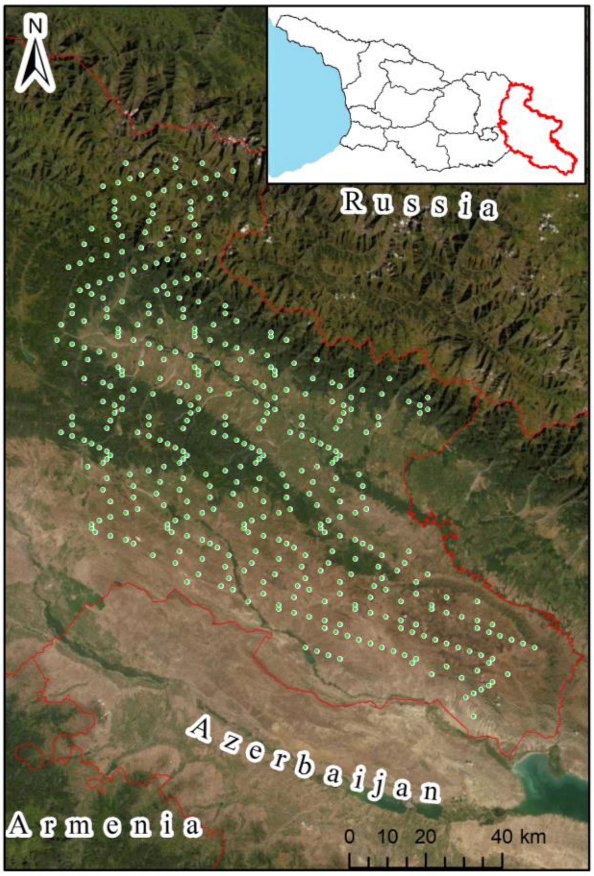


Figure 1. Study Area

Current Research aims comparison different DEM derived landforms. The terrain analysis process involves combining primary attributes to form secondary attributes. Primary attributes include slope, aspect, plan and profile curvature, flow-path length, and upslope contributing area. The secondary attributes that are computed from two or more primary attributes are important because they offer an opportunity to describe the pattern as a function of the process [9]. Terrain shape may be exemplified by steep-ness, slope orientation, and surface curvature, all of which influence surface and subsurface biophysical processes [10]. Avery simple and interesting method for classifying relief on the base DEM is the topographic position index (TPI). TPI is the difference between the elevation at a cell and the average elevation in a neighborhood surrounding that cell. Positive values mean that the cell is higher than its neighbors (indicate ridges, hills, etc.) while negative values mean the cell is lower (indicate canyons, valleys, etc.) [3].

The study area extends over an area of about 11 311 sq. km in eastern Georgia (Fig. 1). The land cover consists mainly of agricultural areas. Its topography varies from extensive lowlands to hilly and mountainous regions. Particularly difficult terrain in the northern part of the region. Fragmentation depth is very deep on the slopes of Caucasus, Pirikita, and Tusheti mountain ranges developed by the Rivers of Pirikita Alazani and Tusheti Alazani. Small valleys covered with alluvium and clay faction are typical landforms [11].

After downloading the tiles of the ASTER GDEM v3 and SRTM 1, the two DEMs are projected to Universal Transverse Mercator (UTM) zone 38 and then clipped to the extent of each test site. 417 GCP were collected from Lidar DEM (fig. 1). For every control point location, the corresponding DEM elevation was extracted.

In order to achieve our goal three-dimension spatial analysis tools available at ArcGIS version 10.8 were applied to calculate the slope, slope aspect, and curvature of SRTM DEM and ASTER GDEM at the location of each GCP. Special tools [12] were used to calculate TPI and classify landforms. To validate the accuracy of the results from each DEM summary statistics of their errors were expressed with Mean Average Error (MAE) and Root Mean Square Error (RMSE).

RESULTS

As outlined in the introduction, our intention was to compare different DEM derived landforms. In this section, we compare ASTER GDEM v3 and SRTM DEM to GCPs from Lidar DEM.

Table 1 quantifies the accuracy of the SRTM DEM and GDEM v3 for the Kakheti Region. It was found that relatively better results were observed in all components in the SRTM DEM. For example, in the vertical accuracy assessment, the MAE was 7.5 m in the SRTM DEM and 10.2 m in the ASTER GDEM v3. Furthermore, the range of ASTER GDEM v3 error with a maximum of 104 m, and a minimum of -81 m is broader than SRTM DEM. The accuracy of SRTM DEM is 11.5 m RMSE. ASTER GDEMv3 presents relatively large residual errors with an RMSE of 14.95 m.

Table 1. Statistical analysis of deviation of SRTM and ASTER GDEM v3

Comparison	**MAE**	**RMSE**	**min**	**max**
ASTER GDEM v3	10.12	14.95	-81	104
SRTM DEM	7.5	11.55	-67	17

Similar behavior was observed in the majority of cases, SRTM DEM revealed considerably higher accuracy. A comparison of slope values revealed a better correlation coefficient in the case of SRTM- 0.87 compared to 0.78 for ASTER GDEM v3 (fig. 2.1. and 2.2.). Reasonable results were obtained from MEA and RMSE which indicate that SRTM has more accurate results with 4.6 MEA and 6.7 RMSE compare to ASTER GDEN v3 with 6.1 MAE and 8.2 RMSE. The values of slope steepness are overestimated in the case of ASTER GDEM. It was found that in both cases, especially in the case of ASTER GDEM v3, inaccuracies occurred mainly in the detection of steep slopes.

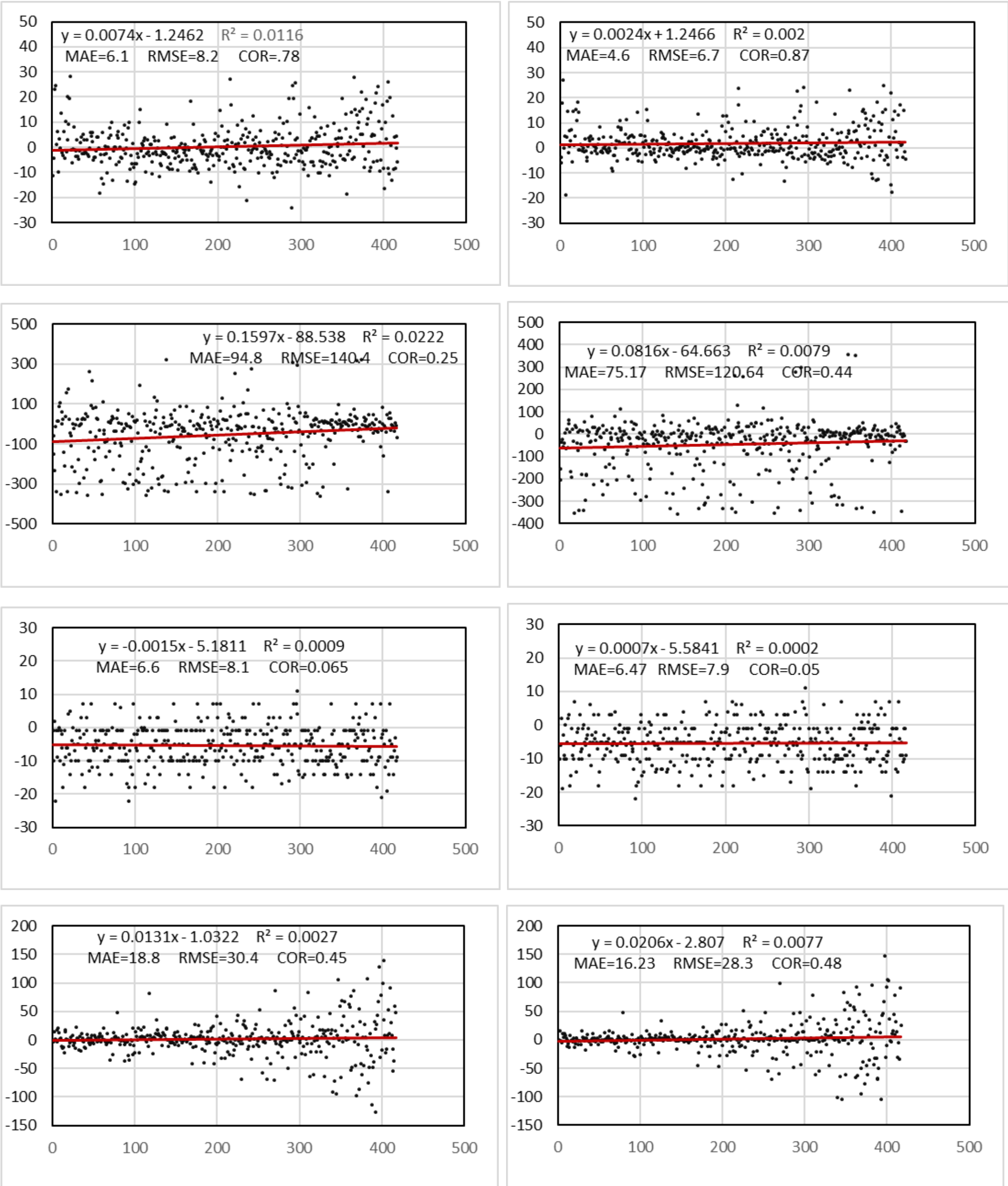
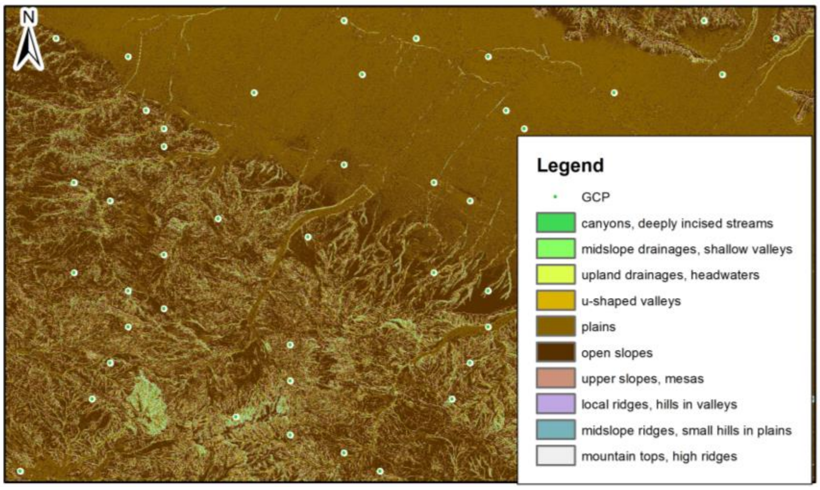
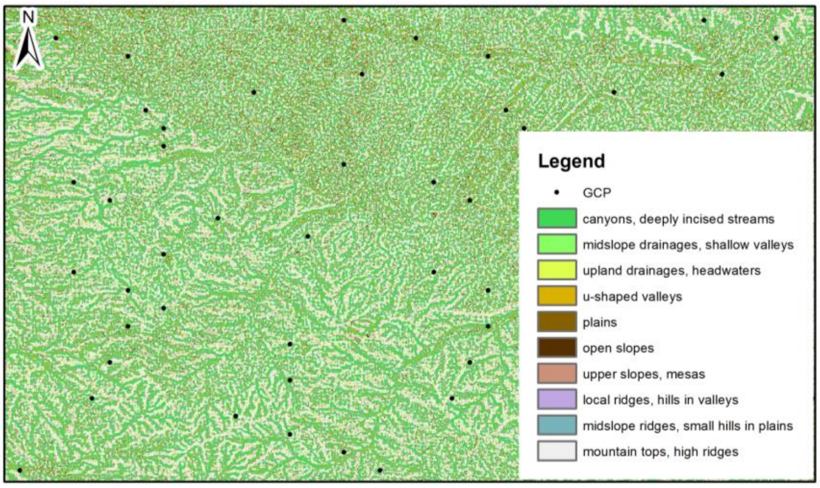


Figure 2. Summary statistics. 1. Lidar slopes vs ASTER GDEM v3 slopes; 2. Lidar Slopes vs SRTM slopes; 3. Lidar slope aspect vs ASTER GDEM v3 slope aspect, 4. Lidar slope aspect vs SRTM slope aspect, 5. Lidar curvature vs ASTER GDEM v3 curvature; 6. Lidar curvature vs SRTM curvature; 7. Lidar TPI vs ASTER GDEM v3 TPI; 8. Lidar TPI vs SRTM TPI.

As for the slope aspect, the results are qualitatively similar, from fig. 2.3.qnd. 2.4 it can be seen that in cases of SRTM DEM the correlation coefficient is moderate (0.44) and the ASTER GDEM v3 correlation coefficient is even lower (0.25). High values of MAE and RMSE, in this case, seem to indicate that more detailed investigations are needed. Nevertheless, this result is only local. It is noteworthy that in this case, inaccuracies are mainly revealed in the case of flat terrain.



A.



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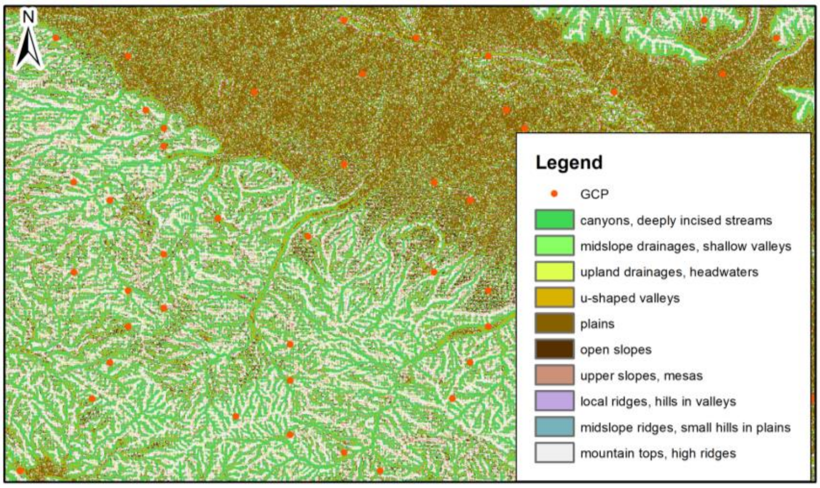

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Figure 2. Landforms: A. Lidar DEM; B. ASTER GDEM; C. SRTM DEM

We also compared terrain curvature; difference distributions are almost identical in both cases. As evident from fig. 2.5 and 2.6. the correlation between both comparable DEMs was very low but relatively lower in the SRTM case.

Comparing figs. 2.7.and 2.8 shows the correlation coefficient of TPI values. It is apparent that correlation coefficients are almost the same in both cases, 0.45 in the case of ASTER GDEM v3 and 0.48 for SRTM DEM.

Finally, the analysis of individual landforms revealed that the main difficulties were related to the modeling of plains, which is well explained by the fact that both DEMs reflect anthropogenic artifacts, which in turn have much effect on individual landforms. A striking illustration of this can be seen in fig. 2 where significant differences are obvious in both cases but still, SRTM DEM corresponds plains and open slopes relatively better than ASTER GDEM v3. Only a few areas (not presented here) especially mountain tops and high ridges, where ASTER GDEM V3 had a small advantage.

It could be inferred therefore that both DEMs have relatively low accuracy in terrain morphometry analysis, SRTM DEM provides compelling evidence to be used in landform analysis with a regional scale.

CONCLUSION

Prior works have documented that different versions of SRTM DEM have a slightly small advantage in terrain morphometry analysis (elevation, slope, etc.) compare to ASTER GDEM. However, these studies have been focused on one or two elements of terrain. In this study we tried to present a general picture. This study evaluated the quality of SRTM DEM and ASTER GDEM v3 and their accuracy in slope, aspect, curvature, TPI, and landform delineation. Our results provide a clear distinction between the two DEMs. SRTM DEM generally proved to be more accurate than ASTER GDEM v3. In most cases, SRTM DEM proved low numbers of MAE and RMSE and a high correlation coefficient. SRTM DEM corresponds to plains and open slopes relatively better than ASTER GDEM v3. Only a few areas especially mountain tops and high ridges, where ASTER GDEM V3 had a small advantage. This finding is promising and should be explored with other DEM data. SRTM DEM and ASTER GDEM v3 would be widely used in landform analysis with a regional scale. Future work should focus on analysis in more diverse terrain.

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