ACCURACY ASSESSMENT OF CONTOUR INTERPOLATION FROM 1:50,000 TOPOGRAPHICAL MAPS AND SRTM DATA FOR 1:25,000 TOPOGRAPHICAL MAPPING

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Commision VII, WG VII/7

KEY WORDS: Topographic mapping, Map revision, Shuttle Radar Topographic Mission data, Contour interpolation, Contour accuracy assessment

ABSTRACT

One major problem engendered by poverty in less-developed countries is that of inability of such countries to carry out fresh medium-scale topographical mapping at regular time intervals using expensive but accurate topographical mapping techniques. For such countries, an alternative which has proved to be cost-effective and efficient over the years is topographical map revision using existing topographical maps, satellite imageries and other free spatial data sources. However, extracting contours from existing topographical maps for inclusion in a new digital topographical map, often at a larger scale, is not usually a straight-forward process due to differences in map units and contour intervals between the existing base maps and the new map. Although free spatial data sources such as the Shuttle Radar Topographic Mission (SRTM) digital data provide excellent base data for extracting height data for topographic mapping, such data sets need to be adequately evaluated and subjected to further processing before extracting contours needed for topographical mapping. Extracting topographical data by contour interpolation from existing topographical maps and SRTM data therefore necessitates accuracy assessment of the interpolation result to ascertain its suitability for topographical mapping. This paper presents a framework for accuracy assessment of interpolating contours from 1:50,000 topographical maps and SRTM height data for topographical mapping at the scale of 1:25,000. Accuracy tests of contours interpolated from the two sources are performed for different terrain configurations and contexts to determine their suitability for topographical mapping in different scenarios. Using an on-going 1:25,000 topographical mapping project as a case study, the use of this contour interpolation accuracy assessment model for arriving at the best strategy for the mapping is also presented.

1. INTRODUCTION

Topography is basic to many earth surface processes and thus finds applications in ecology, hydrology, security, agriculture, climatology, geology, pedology, geomorphology and a host of other domains and constitutes the basis for explaining processes and predicting them through the process of modelling. The tremendous role of topographic mapping in national development continues to receive recognition by national, state and local governments the world over. The importance of topographic mapping as a national project is therefore growing and accurate topographic maps as its major products are considered as indispensable components of national geospatial data infrastructure. In countries with developed and stable economies, a clearly articulated road map is usually made for regular, fresh topographic mapping using current data and the state-of-the-art mapping technologies. In less-developed countries however, the problem of poverty and inadequate technical capacities in the area of geo-information production and management culminate in the inability of such countries to carry out fresh topographical mapping at regular time intervals using expensive but accurate topographical mapping techniques. For such countries, an alternative and cost-effective strategy over the years has been topographical map revision using existing topographical maps, satellite imageries and other readily available spatial data sources. Unfortunately, the process of extracting topographical information (contours) from existing topographical maps and integrating same in a new digital topographical map, often at a larger scale, is usually a lengthy and time-consuming process due to differences in map units and contour intervals between the existing base maps and the new map. Moreover, most of the topographical map sheets to be used as base maps for a revision exercise are either missing or, where they exist, are very old and suffer from severe distortion. This method of topographic mapping therefore turns out to be error-prone, time-consuming and highly-demanding in manpower resources.

A recent development representing a tremendous forward leap in remote sensing technology that will significantly eliminate some of the lacunae associated with topographic map revision from existing topographical maps is the launching of the Shuttle Radar Topography Mission (SRTM) in February, 2000. Using the Synthetic Aperture Radar (SAR) interferometry to produce the first near-global high resolution digital elevation model (DEM) of the Earth, SRTM has created an unparalleled set of global elevations that is freely available for modelling, mapping and environmental applications (Gorokhovich and Voustianiouk, 2006). The global availability (about 80% of the Earth surface, covering land masses between 60ºN and 56ºS) makes it the most widely-used set of baseline elevation information for a

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wide-range of applications and this development has been identified by professionals in the geo-information arena as a significant landmark that will tremendously revolutionize medium-scale topographic mapping. The near-global SRTM digital elevation model (DEM) product was processed and compiled at a resolution of 90m by the Consultative Group for International Agriculture Research Consortium for Spatial Information (CGIAR-CSI) and hosted on a Web portal for free public access and download. Although this product presents attractive promise for terrain analysis for an impressively wide range of applications, several researchers have proposed a thorough evaluation of its vertical accuracy. For instance Gorokhovich and Voustianiouk (2006) in their study to assess the accuracy of the SRTM-based elevation data noted that an overall assessment of the accuracy of the product requires additional regional studies involving ground truth control and accuracy verification methods with higher level of precision. Both the vertical accuracy of the product and its applicability in different contexts have been extensively investigated in many studies (Koch, A. and Lohmann, P., 2000; Miliaresis, G. and Paraschou, C. V. E., 2005: Kocak G. et al, 2005: Koch, A. et al, 2005, Kleusberg, A. and Klaedtke, H. G., 1999). The major objectives of these studies have been to:

- determine the absolute and relative vertical accuracies of the SRTM digital elevation data for defined study sites;
- determine the relationship between SRTM vertical errors and certain topographic derivatives from the SRTM DEM such as slope and aspect;
- evaluate the impact of spatial structure on the accuracy of contour maps derived from the SRTM DEM;
- investigate the effects of geostatistical processing models on the SRTM DEM derivatives.

The enormous attention directed towards regional-level assessment of SRTM vertical accuracy suggests that extracting topographical data by contour interpolation from SRTM elevation data necessitates accuracy assessment of the interpolation result to ascertain its suitability for digital topographical mapping especially at a scale of 1/25,000. In this paper, we present a framework for accuracy assessment of interpolating contours from 1:50,000 topographical maps and SRTM height data for topographical mapping at the scale of 1:25,000. Quantitative statistical and geostatistical tests were performed on the two spatial data sources for different terrain configurations and contexts to determine their suitability for topographical mapping in different scenarios. In particular, this study consisted of:

(1) measuring the vertical accuracy of the DEM derived from the 1:50,000 topographic map and that of the 90-m resolution CGIAR-CSI SRTM digital elevation data against higher precision GPS measurements within the same site;
(2) interpolating digital elevation models from an existing topographic map covering the same area and comparing measurements from the two sources;
(3) implementing a processing strategy to minimize errors emanating from contour interpolation using SRTM data as a base.

Using an on-going 1:25,000 state-wide topographical mapping project undertaken by one of the State Governments of Nigeria as a case study, we demonstrate the applicability of the proposed contour interpolation accuracy assessment model for arriving at the best strategy for the topographical mapping process. The rest of the paper is organised as follows. Section 2 describes the site chosen for this study. Section 3 is dedicated to a description of the materials and the methodology adopted for the study. Section 4 presents a discussion of the results of the GIS analysis and geostatistical processing methods adopted while Section 5 concludes the paper.

2. STUDY SITE

The site chosen for this study lies between Latitudes 5º30' E and 5º 45' E and Longitudes 7º 15'N and 7º30'N. The site is situated in Ondo State, a state in the South-Western part of Nigeria. Figure 1 shows a digital elevation model (DEM) of the site presented as a color-coded image. The chosen site corresponds to the area covered by one map sheet at the scale of 1/50,000 (27.8Km X 27.5Km). The site covers low-level, mid-level and high-altitude terrain with elevations ranging from 182m to 594m above mean sea level. The mean elevation of the site is 284m above mean sea level. As depicted in Figure 1, the South-Eastern part of the area is generally low-lying with elevations ranging from 182m above mean sea level to 285m above mean sea level. The North-Eastern part is characterized by rugged terrain interspersed with hills having elevations ranging from 490m to 594m above mean sea level. The rest of the area is generally at mid-level altitudes with elevations ranging from 285m to 388m above mean sea level. The entire area is well-drained with a good network of rivers and streams all flowing Southwards. The predominant vegetation in this area is of tropical rain forest type with dense canopy cover in some areas and low, widely separated trees in others. The hilly areas present exposed rock surfaces in some areas and low grasses and shrubs in others. This site was deliberately chosen by reason of the fact that it presents different topographic conditions (from low to high terrain characteristics) for the purpose of conducting statistical and geostatistical analyses presented in this study.

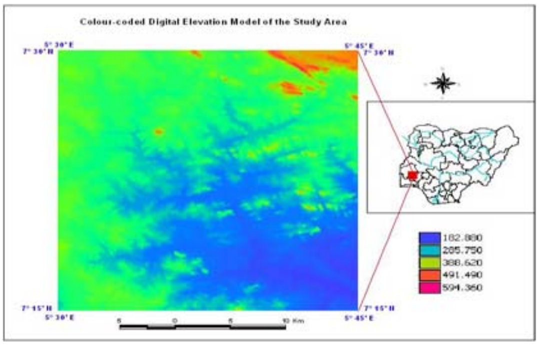


Figure 1. The study site as oolor-coded Digital Elevation Model

3. DATA, MATERIALS AND METHODS

3.1 Source Data

The accuracy tests conducted in this study employed three major sources of spatial data (90-m resolution CGIAR-CSI SRTM digital elevation data, 1/50,000 topographical map of the study site and GPS point data randomly distributed over the study site).

The SRTM Digital Elevation Model was processed and maintained by the Consultative Group for International Agriculture Research Consortium for Spatial Information (CGIAR-CSI). In the form compiled and maintained by CGIAR-CSI, the SRTM elevation data have a spatial resolution of 90m. This data set is seamless with all voids filled using a methodology based on spatial filtering (Gorokhovich and Voustianiouk, 2006). The CGIAR-CSI SRTM 90m digital elevation data sets are provided to the general public in 5º X 5º tiles in computer-compatible raster formats (GeoTiff and ARC/INFO ASCII Grid). The data set is in LatLon coordinate system projected on the WGS 84 Ellipsoid. For the purpose of our study, one of the tiles covering the chosen study site was downloaded from the CGIAR-CSI Web site at http://srtm.csi-cgiar.org.

One topographic map sheet at the scale of 1/50,000 covering the chosen study site was selected for use as a reference for analyzing the SRTM elevation data. The map sheet was digitized into layers (hypsometry, hydrography, transportation and built-up) as part of the input data sets within the framework of an on-going state-wide topographical mapping project undertaken by the Ondo State Government of Nigeria. In this accuracy assessment study, only the hypsometric and hydrographic layers were obtained from the project consultants. The selected layers were digitized from an existing paper map sheet compiled in 1965. The map was based on the UTM projection (Zone 31) on Clarke 1880 Ellipsoid and had a contour interval of 50 feet.

GPS elevation data used in this study were acquired during a field truthing mission organized by the Ondo State Topographical Mapping project consultants as part of activities within the framework of the state-wide 1/25,000 topographical mapping project. During the GPS survey exercise, GPS measurements were made with a vertical accuracy of $\pm$ 1m at randomly visited points. Since the GPS observations were meant to validate contours interpolated from the existing topographical maps, they were originally transformed into the coordinate system of the maps (UTM projection on Clarke 1880 Ellipsoid).

3.2 Materials

Three major software packages were employed for the processing of the data and the visualization and analysis of the results. These included the royalty-free, open-source Integrated Land and Water Information System (ILWIS 3.4), ArcGIS 9.2 (proprietary) and Microsoft Excel. In addition, we developed a number of in-house programs in Visual Basic 6.0 for performing some specialized functions such as coordinate transformation, terrain profiling and elevation data extraction from ASCII raster data sets.

3.3 Methodology

The methodology adopted in this study was in keeping with the main objectives of the study as stated in Section 1 of this paper.

3.3.1 Data preparation: The data sets employed in this study emanated from disparate sources based on different formats, coordinate systems and projections. The first step in the exploitation of the data sets was therefore the transformation of all the data sets into a common system. Since the CGIAR-CSI SRTM 90m digital elevation data sets were in LatLon WGS84 system, the topographic map layers (contours and rivers) and the GPS elevation data in UTM Clarke 1880 system were transformed into the LatLon WGS84 system using tools available in ILWIS 3.4 software. To restrict the test to the chosen study site, it was expedient to extract only the GPS points that fell within the extents of the study area. To perform this operation, we implemented a small program in Visual Basic 6.0 to clip the GPS point set using the extents of the study site. Using our program, the hypsometric layer with contour values in feet was metricated by transforming it into a new layer with all the contour values multiplied with a Z-factor of 0.3048

Since our study also involved the accuracy tests of contour interpolation from the 1:50,000 topographical map, it was necessary to process the source 1:50,000 topographic map into a form appropriate for the test. To satisfy this requirement, we created a grid-based digital elevation model with a resolution of 90m (corresponding to the resolution of the CGIAR-CSI SRTM DEM) from the metricated 1:50,000 topographic map using the contour interpolation function available in ILWIS 3.4. This involved first rasterizing the contour map layer and then interpolating between the isolines using the method described in Gorte, B.G.H. and Koolhoven W. (1990).

3.3.2 Determination of the vertical accuracy of Topo DEM and SRTM DEM: Several publications on the accuracy of CGIAR-CSI SRTM 90m elevation data report that its absolute vertical accuracy is in the order of $\pm$ 16m (Koch, A. and Lohmann, P., 2000; Miliaresis, G. and Paraschou, C. V. E., 2005; Muller, J. P., 2005). This accuracy value has been extensively tested in different regions under different terrain characteristics by many researchers (Giacomo F. et al, 2005; Brown, C. G. et al, 2005). Results of such tests showed that the absolute vertical accuracy of the SRTM elevation data depends on terrain characteristics. In Gorokhovich and Voustianiouk (2006) for example, it was shown that two topographic derivatives, slope and aspect, significantly influence the absolute vertical accuracy value. The study showed that steeper slopes recorded higher vertical errors than gentler slopes, while SRTM data underestimated elevations with North West aspect and overestimated elevations with South East aspect. In our study, emphasis was placed only on the absolute vertical accuracy of Topo DEM and SRTM data covering our study site.

Determining the absolute vertical accuracy of SRTM data basically involves computing the standard deviation statistic of the elevation differences between the SRTM data and a reference data set such as GPS point measurements. This requires overlaying the GPS points on the SRTM and extracting the heights from the two data sets at their position of coincidence and using these values to compute the accuracy statistic. Gorokhovich and Voustianiouk (2006) described a method for performing the overlay. Their approach involved first converting the SRTM raster data set into a vector-based GIS layer containing as many polygons as there were grid cells in the SRTM data and then performing a spatial join of the point data and the new polygonal layer to extract the height data for the statistical analysis. This method may prove to be highly demanding in computer memory and may turn out to be computationally-intensive to handle especially where the point data set is large. In our study, we adopted a simpler method of performing the spatial join. Our approach involved projecting the X, Y Cartesian coordinates of the point data into their equivalent grid image space (rows and columns). These rows and columns were then used to access the value stored at the corresponding grid cell location. We implemented a small Visual Basic program (using the MapWindow programmable

ActiveX GIS control) to perform this operation. The result was a dBase table which was imported into Microsoft Excel environment to perform the statistical analysis. The results of the computation are summarized in Table 1 below. The table shows that the absolute vertical accuracy of the CGIAR-CSI SRTM elevation data for our study site is ± 7.748m and a mean difference in elevation between the two data sets is 3.539m. Figure 2(a) depicts a graphic plot of the GPS elevations against the SRTM elevations. The coefficient of correlation and F-statistic between the two data sets were respectively +0.993094578 and 0.767496217. These results indicate a strong positive correlation between the two data sets.

Since this study also involved determining the vertical accuracy of the DEM derived from the 1:50,000 topographic map, this statistic was computed by applying the same method described for the SRTM data. The results of the statistical computation are presented in Table 2. The results show that the absolute vertical accuracy of the topo DEM for our test site was ± 3.926 and a mean value of -0.151m. A graphic plot of the GPS elevations against the topo elevations is as depicted in Figure 2(b). The coefficient of correlation for the data set was +0.998253 with an F-statistic of 0.990632.

Statistical Measure	SRTM Elevation (m)	GPS Elevation(m)	Δ H (SRTM-GPS)(m)
Minimum	190.000	184.324	-19.996
Maximum	489.000	507.168	17.162
Mean	327.308	323.768	3.539
Std Dev.	± 63.425	± 65.101	± 7.748
Count	130	130	130

Table 1: Statistical analysis of SRTM and GPS elevation data

Statistical Measure	Topo Elevation (m)	GPS Elevation(m)	Δ H (Topo-GPS)(m)
Minimum	182.88	184.324	-18.985
Maximum	502.92	507.168	18.542
Mean	326.568	323.768	-0.151
Std Dev	± 66.38	± 65.101	± 3.926
Count	139	139	139

Table 2 Statistical analysis of Topo and GPS elevation data

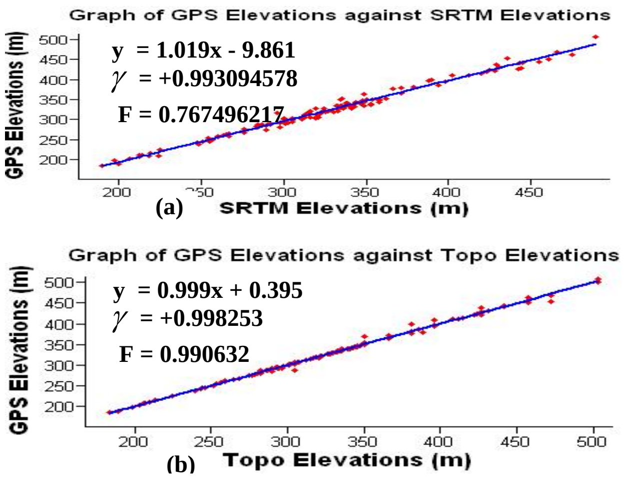
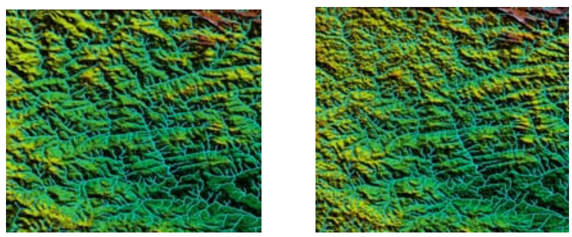


Figure 2. Graph of GPS elevations against
(a) SRTM elevations (b) Topo elevations

3.3.4 Comparison of the SRTM DEM and the Topographical DEM surfaces: For contours interpolated from the SRTM DEM to be deployed in 1/25,000 topographic mapping, the accuracy with which the DEM represents the surface morphology must be tested and proved to be of a sufficiently high degree. In this study, we employed two methods to test the accuracy of the SRTM data for good terrain representation. The methods involved the following

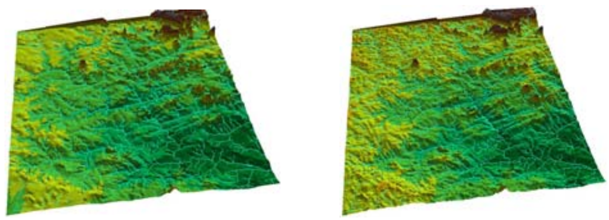
(1) interpolating a DEM from the topographical map with the same spatial resolution as the SRTM DEM and visually comparing the two surfaces;
(2) generating profiles along defined transects on the two surfaces and visually comparing the plots.

The above operations required that the two DEMs must have the same spatial resolution, georeference and spatial extent. To satisfy this requirement, the output DEM from the topographical map with a resolution of 90m was trimmed to the size of the SRTM DEM. Both grid-based DEMs were converted into TIN-based DEMs in the ArcGIS 9.2 environment and overlaid with the hydrographic layer. The results of this operation are as shown in Figure 3 (a) and Figure 3(b). Figure 4(a) and Figure 4(b) show the perspective views of the two DEMs.



(a) (b)

Figure 3 TIN-based DEMs with the hydrographic network superimposed (a) Derived from 1/50,000 Topo Map
(b) Derived from SRTM Grid



(a) (b)

Figure 4. Perspective views of derived DEMs with hydrographic network superimposed
(a) Topo DEM (b) SRTM DEM

Further analysis of the SRTM surface involved a comparison of height profiles on the two surfaces. Two transects running from SW to NE and NW to SE were created on the two DEMs. To extract the elevations for the profile plot, we implemented a small Visual Basic 6.0 program to project the transects onto the DEM surfaces and to extract elevations from the two surfaces at regular intervals. The result of the computer run of the program was a dBase table containing the elevations along the transects on the two surfaces and the cumulative distances from the starting points of the profiles. The table was imported into

ILWIS 3.4 and profiles plotted. Figure 5 shows an example of the terrain profile along one of the transects.

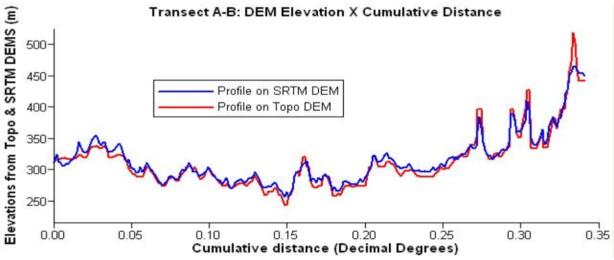


Figure 5. Terrain profile along Transect A-B

3.3.5 Assessment of the cartographic quality of the SRTM DEM: One major requirement for deploying contours interpolated from SRTM elevation data in 1/25,000 mapping is that the contours must be of good cartographic quality. However, SRTM DEMs have been shown to suffer from a number of gross, systematic and random errors propagated from the Synthethic Aperture Radar (SAR) imaging system. As demonstrated by Koch, A. and Lohmann, P., (2000), SAR imaging system is affected by errors due to baseline tilt angle, baseline length, platform position, phase and slant range. These errors are known to affect the accuracy and the quality of SRTM DEM and its derivatives such as slope, aspect and contours. In contours interpolated from the SRTM DEMs for example, such errors may manifest as artefacts such as short pieces of unclosed contour lines, self-intersecting contour lines and contour lines intersecting other contour lines with different contour values. The issue of correcting errors in digital elevation models has received the attention of many researchers. For example Ping Wang (1998) employed 2-D Kalman filtering approach to generate optimal estimates of terrain variables from a noisy DEM. The approach comprised of using a 2-D Kalman processor, a function for outlier detection and a two-step filtering procedure. More recently, Emanuel Mahler (2001) implemented the wavelet transform model for scale-dependent filtering of high resolution digital terrain models. In our study, we investigated the cartographic quality of contours interpolated directly from SRTM DEM. The objective was to determine the suitability of using such a product in 1/25,000 topographical mapping and to propose, employ and evaluate a methodological approach in order to determine its effectiveness in improving the cartographic quality of contours derived from SRTM DEMs. The steps involved in this accuracy assessment method were:

(1) interpolating contours directly from the SRTM 90m DEM and visually inspecting the quality of the contours
(2) re-sampling the SRTM 90m DEM to twice the resolution (45m) and visually analyzing contours derived from the new DEM;
(3) subjecting the SRTM 90m DEM to further processing by re-interpolating the surface from its elevation data and visually analyzing the quality of contours derived from the new product;
(4) visually comparing the results of the above procedures.

The goal of the first step above was to visually assess the cartographic quality of contours interpolated from the CGIAR-CSI 90-m resolution SRTM DEM without subjecting it to further processing. To achieve this goal, the contour interpolation function available in ArcGIS 9.2 GIS was used to create a vector contour map with a vertical interval of 5m (a vertical interval value recommended for a 1/25,000 topographic mapping). A small window extracted from the resulting contour map is presented in Figure 6(a). From this map extract, it can be seen that direct interpolation of contours from the 90-m resolution SRTM DEM produces artefacts as highlighted in the encircled areas of the map.

The second step in the assessment of the cartographic quality of the SRTM data was executed to visualize the impact of further processing of the data set on its cartographic quality. This procedure involved simply applying a pixel densification operation by a process of raster re-sampling. In this study, we executed this process by performing a cubic interpolation of the 90-m resolution SRTM DEM to re-sample the data from 90m to 45m. The result of this operation is presented in Figure 6(b) as a map extract using the same window coordinates as in the first step.

The third step in the assessment of the cartographic quality of the SRTM data involved re-interpolating the SRTM DEM surface from a point raster map derived from the SRTM DEM using the Inverse Distance Weighted (IDW) point interpolation function. The principle of this interpolation technique, also called the moving surface function, is well documented in the literature (see, for instance, ILWIS, 2001). This technique involves determining a new output value for a given cell by fitting a polynomial surface through all points weighted by their individual weight factors considering only points that fall within a certain limiting distance (search radius) towards this pixel. The weight functions ensure that points close to an output pixel obtain a larger weight value than points which are farther away from an output pixel. In this study, we executed this interpolation operation by adopting a methodological approach as follows. First a point map was created by running a small Visual Basic 6.0 program developed in-house. The program created a point map in which the points corresponded to the centres of the cells in the SRTM 90m grid-based map. The point map (with SRTM DEM heights as attributes) was then imported into the ILWIS 3.4 environment where its variogram surface was calculated. The calculated variogram surface enabled an optimal search distance for the moving surface interpolation to be established. For the point data set covering our study site, this value was found to be 2.5 times the grid cell size. The actual interpolation was executed in ArcGIS 9.2 environment using the IDW interpolation function. This operation was executed twice (for 90-m and 45-m resolutions) each time setting the search distance of 2.5 times the cell size and a weight exponent of 2. The resulting raster grid map was then passed to a contour interpolation function to create a 5-m vertical interval contour map. The resulting contour maps are presented in Figures 6 (c) and (d).

To further visualize the spatial relationships between the three resulting contour maps above, we extracted a small portion of these maps and overlaid them in the ArcGIS 9.2 GIS environment as shown in Figure 6(e). To investigate the degree of fitness of the hydrography with the derived contour maps, we super-imposed the hydrographic network as shown in Figure 6(f).

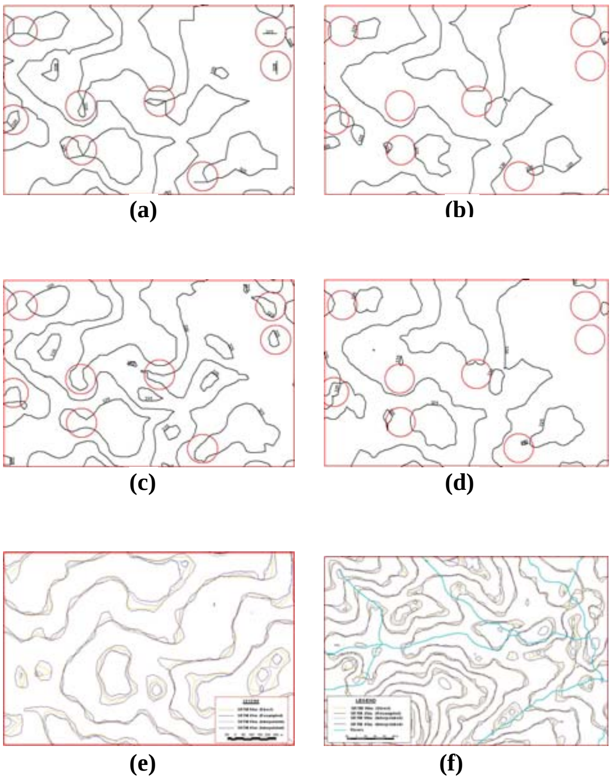


Figure 6. Contours interpolated from SRTM DEM
(a) 5-m vertical interval contours directly interpolated from the 90-m SRTM DEM showing artefacts in circles
(b) 5-m vertical interval contours interpolated from the 90-m DEM derived from the 1:50,000 topographic map by moving surface interpolation
(c) 5-m vertical interval contours interpolated from the SRTM DEM re-sampled to 45m by cubic interpolation
(d) 5-m vertical interval contours interpolated from the 45-m DEM derived from the 1:50,000 topographic map by moving surface interpolation
(e) Super-imposition of the maps from (a) – (d) above
(f) Super-imposition of the maps from (a) – (d) above and the hydrographic network

4. RESULTS AND DISCUSSION

The various tests conducted in this study to assess the accuracy of contour interpolation from the 1:50,000 topographic map and the SRTM elevation data to investigate their suitability for 1/25,000 topographic mapping revealed striking characteristics about the data sets. The statistical computation for the absolute vertical accuracy of CGIAR-CSI SRTM elevation data for our study site gave a value of ±7.748m. This statistic indicated that, for our study area, the 90-m CGIAR-CSI elevation data featured a much greater absolute vertical accuracy than the absolute vertical accuracy value of ±16m published in the SRTM data specification. The statistical tests also revealed that the absolute vertical accuracy (±3.926m) of the digital elevation data derived from the 1:50,000 topographic map covering our study site was much higher than that of the CGIAR-CSI SRTM DEM. The graphic plots of the GPS elevations against the SRTM and topo DEM (Figure 2(a) and Figure 2(b)) revealed that the two data sets showed strong positive correlations with the GPS data. This suggests that the two surfaces are significantly close to the real surface for our study site. The degree of nearness of the two surfaces to reality can also be seen from the high F-statistic values of the two data sets (0.767496217 for the SRTM elevation data and 0.990632 for the topo DEM data). These values indicate that the topo DEM is a more accurate surface than the SRTM DEM, a finding that informed our using the topo DEM as a reference surface for the analyses of the SRTM DEM throughout the rest of the study.

The computed TIN-based SRTM and topo DEMs overlaid with the hydrographic network covering the study site (Figure 3(a), Figure 3(b), Figure 4(a) and Figure 4(b)) revealed striking characteristics of the two surface representations. The overlay showed that the hydrographic network matched the two surfaces well, with the rivers passing through the water courses in the two DEMs. This is a particularly interesting result noting that the two surfaces were derived from two disparate sources (1:50,000 topographic map and SRTM data) with the hydrographic network layer coming from the topographic map data source. The terrain profile presented in Figure 5 further revealed that the two surfaces are generally close, implying that SRTM elevation data can be used as a substitute for the topographic map elevation data for 1:25,000 topographical mapping.

The results of the various tests conducted to assess the cartographic accuracy of the CGIAR-CSI SRTM elevation data are as presented in Figures 6(a) – (f). The tests essentially involved direct interpolation of 5-m vertical interval contours from the SRTM DEM, recreation of the SRTM surface by re-sampling and point interpolation and super-imposition of the various maps for visual interpretation. Based on a visual interpretation of the results, the following facts can be deduced about the CGIAR-CSI SRTM:

(1) Direct interpolation of contours from the 90-m SRTM DEM without further processing produces artefacts in the form of incomplete contour lines, self-intersecting contour lines and contour lines intersecting other contour lines having different contour values (see Figure 6 (a) showing artefacts in encircled areas of the map). This result is a strong indication that contour maps directly derived from the SRTM DEM are generally of low cartographic quality and are not recommended for deployment in 1:25,000 topographic mapping without prior processing.

(2) Processing the SRTM DEM before interpolating contours from it produces results with significantly better cartographic quality than direct interpolation. This observation can be clearly seen in Figures 6(b) – (d) which respectively show the results of moving surface interpolation (90m) of the derived point raster set, the 45-m re-sampling of the 90-m resolution SRTM DEM and the moving surface interpolation (45m) of the derived point raster set. In all these output contour maps, it can be seen that the artefacts present in the directly interpolated contour map are clearly absent, giving a strong indication that further processing of the 90-m SRTM elevation data is required to ensure good cartographic quality of the derived contour maps for 1:25,000 topographic mapping.

(3) The forms of the contour lines emanating from processed and unprocessed SRTM DEM are essentially the same. This can be seen from Figure 6(e) depicting a super-imposition of the contour maps from the three cases cited above. This result is a good indication that further processing of the

SRTM DEM does not significantly distort the terrain as represented by the 90-m SRTM DEM. This can also be seen in Figure 6 (f) which shows that the hydrographic network fits well with the contour maps derived from the SRTM DEM using the three methods described above. Again, this is a strong indication that further processing of the 90-m SRTM elevation data is required to ensure good cartographic quality of the derived contour maps for 1:25,000 topographic mapping.

5. CONCLUSIONS

This study investigated the accuracy of contour interpolation from SRTM and existing 1:50,000 topographical maps. The various processing tasks executed were based on the 90-m resolution CGIAR-CSI SRTM elevation data, a 1:50,000 topographic map of the test site and GPS readings acquired during a field truthing mission executed within the framework of an on-going state-wide 1:25,000 topographic mapping of Ondo State, in the South Western part of Nigeria. The topographic mapping project was originally executed using existing 1:50,000 topographic maps of the area as the base for extracting both planimetric and altimetric data. This study was therefore conducted to compare the accuracy of contours interpolated from the two sources in order to determine their suitability for deployment in the 1:25,000 topographical mapping. The following findings were made from this study:

(1) both SRTM elevation data and elevation data from existing 1:50,000 topographic maps can be used to create a good representation of the terrain, judging from their high positive correlation with the more accurate GPS height data of points within the same site;
(2) the 90-m resolution SRTM DEM manifests artefacts and a prior processing of the data is recommended to achieve cartographic quality good for 1:25,000 topographical mapping.

These findings therefore indicate that 90-m resolution SRTM elevation data can be used as a substitute for existing 1:50,000 topographic maps with the caveat that the former be processed prior to topographic information extraction for 1:25,000 topographical mapping. To satisfy this requirement, the methodological approach (based on point interpolation using the moving surface function) proposed and tested in this study can be adopted.

The analysis of the results emanating from the methodological approach proposed in this study for processing the SRTM data prior to contour interpolation was basically qualitative. In order to better conduct the analysis and assessment of the accuracies of the derivatives from the two elevation data sources used in this study, the applicability of other processing techniques proposed in the literature (such as wavelet transforms and Kalman filtering) in this context need to be further investigated.

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