IT ISSN 0391 - 9838

Bollettino del Comitato Glaciologico Italiano - ser. 3

# GEOGRAFIA FISICA e DINAMICA QUATERNARIA

An international Journal published under the auspices of the
*Rivista internazionale pubblicata sotto gli auspici di*

Associazione Italiana di Geografia Fisica e Geomorfologia
and (e) Consiglio Nazionale delle Ricerche (CNR)

recognized by the (*riconosciuta da*)

International Association of Geomorphologists (IAG)

**volume 43 (1)**
2020

COMITATO GLACIOLOGICO ITALIANO - TORINO
2020

# GEOGRAFIA FISICA E DINAMICA QUATERNARIA

A journal published by the Comitato Glaciologico Italiano, under the auspices of the Associazione Italiana di Geografia Fisica e Geomorfologia and the Consiglio Nazionale delle Ricerche of Italy. Founded in 1978, it is the continuation of the «Bollettino del Comitato Glaciologico Italiano». It publishes original papers, short communications, news and book reviews of Physical Geography, Glaciology, Geomorphology and Quaternary Geology. The journal furthermore publishes the annual reports on italian glaciers, the official transactions of the Comitato Glaciologico Italiano and the Newsletters of the International Association of Geomorphologists. Special issues, named «Geografia Fisica e Dinamica Quaternaria - Supplementi», collecting papers on specific themes, proceedings of meetings or symposia, regional studies, are also published, starting from 1988. The language of the journal is English, but papers can be written in other main scientific languages.

*Rivista edita dal Comitato Glaciologico Italiano, sotto gli auspici dell'Associazione Italiana di Geografia Fisica e Geomorfologia e del Consiglio Nazionale delle Ricerche. Fondata nel 1978, è la continuazione del «Bollettino del Comitato Glaciologico Italiano». La rivista pubblica memorie e note originali, recensioni, corrispondenze e notiziari di Geografia Fisica, Glaciologia, Geomorfologia e Geologia del Quaternario, oltre agli Atti ufficiali del C.G.I., le Newsletters della I.A.G. e le relazioni delle campagne glaciologiche annuali. Dal 1988 vengono pubblicati anche volumi tematici, che raccolgono lavori su argomenti specifici, atti di congressi e simposi, monografie regionali sotto la denominazione «Geografia Fisica e Dinamica Quaternaria - Supplementi». La lingua usata dalla rivista è l'Inglese, ma gli articoli possono essere scritti anche nelle altre principali lingue scientifiche.*



INDEXED/ABSTRACTED IN: Bibliography & Index of Geology (GeoRef); GeoArchive (Geosystem); GEOBASE (Elsevier); *Geographical Abstract*: *Physical Geography* (Elsevier); GeoRef; Geotitles (Geosystem); Hydrotitles and Hydrology Infobase (Geosystem); Referativnyi Zhurnal.
Geografia Fisica e Dinamica Quaternaria has been included in the Thomson ISI database beginning with volume 30 (1) 2007 and now appears in the Web of Science, including the Science Citation Index Expanded (SCIE), as well as the ISI Alerting Services.

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Printed with the financial support from (pubblicazione realizzata con il contributo finanziario di):

- Comitato Glaciologico Italiano
- Associazione Italiana di Geografia Fisica e Geomorfologia
- Ministero dell'Istruzione, Università e Ricerca
- Consiglio Nazionale delle Ricerche
- Club Alpino Italiano

*Geogr. Fis. Dinam. Quat.*
*43 (2020). 157-165, 3 figg., 3 tabb.*

DOI 10.4461/ GFDQ.2020.43.6

Ivan HENRICO [1*], Susan HENRICO [2] & Serena COETZEE [3]

# A COMPARISON BETWEEN TWO DEM PRODUCTS TO CALCULATE A VISIBILITY ANALYSIS FOR MILITARY OPERATIONS USING FOSSGIS

**Abstract:** Henrico I., Henrico S. & Coetzee S., *A comparison between two DEM products to calculate a visibility analysis for military operations using fossgis.* (IT ISSN 0391-9838, 2020).

Visibility analysis, commonly known as viewshed, is a valuable function in any geographic information system (GIS) and is a critical tool used for many applications, including the military, for representing the overall visibility and surface characteristics of the terrain. The first step to perform a visibility analysis is selecting the digital elevation model (DEM). This study conducted a comparative viewshed analysis, utilising the TanDEM-X 90m and the SRTM 30m DEM products to determine if the lower resolution DEM is suitable to deliver accurate and reliable viewshed analysis results for military purposes. Strategically placed observer points were used to calculate the viewshed analysis and determine if specific target areas (military bases) are visible or not. It was interesting to note that all military bases were either visible or not visible from all observer point locations for both DEMs utilised, however it is unavoidable that the accuracy of a visibility analysis is influenced by the quality of the elevation data source.

**Key words:** DEM, Viewshed analysis, Geographic Information System.

## INTRODUCTION

A viewshed analysis indicates areas that are visible to an observer in all directions. It is widely used in many applications such as the military, security, telecommunications, agricultural and landscaping to derive geomorphometric and/or morphometric parameters or to obtain general terrain information (Badura & Przybylski, 2005; Bolongaro-Crevenna & *alii*, 2005; Chaplot & *alii*, 2006; Knowles & *alii*, 2008; Pike & *alii*, 2009; Lagner & *alii*, 2018). This study only focuses on the military application of a viewshed analysis as a geospatial functionality that provides important information to the military commander about the theatre of operation, whether it is in support of humanitarian aid, peacekeeping and peach enforcement operations or even conventional warfare.

In literature, numerous viewshed analysis studies have been conducted that utilise DEMs to solve specific every-day problems, such as the placement of telecommunication towers to determine the best possible location for continuous coverage over a specific area (Dodd, 2001; Kim & *alii*, 2004; Benham, 2012; Edan & *alii*, 2013; Heyns & Van Vuuren, 2013; Johnson, 2015; Henrico & *alii*, 2016). Other studies utilise viewshed analysis for urban planning, landscape analysis and disaster management (Pyysalo & *alii*, 2009; Šiljeg & *alii*, 2017; Petrasova & *alii*, 2018; Hognogi & *alii*, 2020). Most studies when conducting viewshed analysis utilises global or near-global elevation data sources, such as Shuttle Radar Topography Mission [SRTM] (Rodriguez & *alii*, 2006), TanDEM-X (Fritz & *alii*, 2011; Rossi & *alii*, 2012; Zink & *alii*, 2014), Advanced Spaceborne Thermal Emission and Reflection Radiometer [ASTER], Global Digital Elevation Model [GDEM] (Abrams, 2000), Global Multi-resolution Terrain Elevation Data 2010 [GMTED2010] (Danielson & Gesch, 2011), and Advanced Land Observing Satellite (ALOS) World 3-Dimensional - 30m [AW3D30] (Stamatiou & *alii*, 2018) to conduct the research. Various techniques (airborne photogrammetry, airborne laser scanning, cartographic surveys, ground surveys, and stereo- or radar-based satellite imagery) are also used to generate digital elevation data sources (Hengl & *alii*, 2003; Malik & Kumar, 2018; Aleshin & *alii*, 2020). Conversely, most of these sources and techniques are expensive to acquire and apply, especially by Defence Forces of poor countries. In such instances, remotely sensed satellite images and freely available

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*This paper has been selected for publication among those presented at the ICMG19 - 13th International Conference on Military Geosciences held in Padua (Italy) from 24th to 28th June 2019 on behalf of the International Association for Military Geoscience (IAMG)*

elevation data are used and is the most productive way to spatially support military operations.

This study compares two freely and near-global elevation datasets with each other and contributes to military science by interpreting the results for military operations. This expands existing knowledge about conducting a viewshed analysis for military purposes and the effect that different quality levels of elevation data have on terrain visibility. It is imperative to comprehend the meaning of data quality before conducting any geospatial analysis, because specific framework exists for using such data. The International Organization for Standardization (ISO) standard on data quality provides a framework for selecting data for an intended use or application, evaluating data quality and describing the quality of data according to six dimensions, namely completeness, logical consistency, thematic accuracy, temporal accuracy, positional accuracy and usability, *ISO 19157:2013: Geographic information - Data quality* (Cooper & *alii*, 2011).

In the military, completeness, accuracy and reliability of information are crucial. A viewshed analysis is conducted to enhance and assist mission planning functions (table 1). It allows a geographic information system (GIS) operator to create 3-Dimensional (3D) visualising maps from visibility analyses which provide the commander with the required critical information (Henrico, 2017).

TABLE 1 - Military functions supported by a viewshed analysis

| Type of Military Functions | Description |
|---|---|
| Communications | Line-of-sight is a principle of radio transmissions and no visibility indicates that the path between antennas is obscured which will create poor or no radio signal. Relay stations can be deployed to elevate the situation where radio signals are obscured. |
| Threat domes | Threat domes are defined as a 3D element and can be used to build a zone around a potential threat. These types of products are normally used to indicate the possible deployment and range of weapon and radar systems. |
| Placement of observation points | A visibility analysis provides the means to determine observer positions by indicating areas that are visible or not. |
| Placement of equipment | The placement of snipers or artillery weapons can be determined by a viewshed analysis and can provide a target-hit probability analysis on the placement of military weapons and equipment. |
| Indicating no-flying zones | No-fly zones are areas where airplanes are not allowed to fly and is used to prevent aircraft in these areas for either safety reasons or security. |
| Movement | Route planning is an essential element to ensure successful military operations. The ability to negotiate the terrain and determine the optimum route for the movement of troops and military vehicles is critical to the planning of any military operation. A viewshed analysis allows for the interpretation of terrain data to identify obstacles and provide the military commander with various movement solutions within an operational area. |

Source: Van Hekken and Van Oosterom (1995); Gertler & *alii* (2011); Larsen (2015).

Accurate elevation data will ensure that the best strategic position and most suitable location is selected for placing an observer point. It is required to have a complete representation of the terrain that shows the layout of the entire area of operation when conducting a viewshed analysis. This will ensure that all terrain is considered during the viewshed analysis. Having an incomplete picture of the terrain or missing terrain data will create a skew and inadequate product that will be useless to the military commander. Therefore, the most important requirement for creating a reliable viewshed analysis in a military environment is the use of accurate elevation data.

## RESEARCH METHODOLOGY

The aim of this study was to determine the suitability of the recently released TanDEM-X 90m (3 Arc-Second) DEM when compared with the earlier released and well-known SRTM 30m (1 Arc-Second) Global Void-Filled DEM to calculate a viewshed analysis for military operations. These two products will henceforth be referred to as the TDM30 and SRTM30. This analysis considers the visible area estimations from three different observation points to seven target points identified within the area of operation (AOI) (fig. 1). The OPs were placed on strategic locations within the AOI:

a) A = OP 1,
b) B = OP 2, and
c) C = OP 3.

The target areas consist of seven military bases in the Cape Town region, identified from Google Maps, namely:

a) 1 = AFB Ysterplaat,
b) 2 = SAS Wingfield,
c) 3 = Cape Town Highlanders HQ,
d) 4 = Youngsfield Military Base,
e) 5 = 2 Military Hospital,
f) 6 = SAS Simon's Town, and
g) 7 = 9 SA Infantry Battalion Base.

The visible area estimations of both the TDM90 and SRTM30 were compared to determine if the TDM90 is suitable to deliver accurate and reliable viewshed analysis results for military purposes. All analyses were conducted using the free and open-source GIS (FOSSGIS) platform, namely QGIS. The QGIS "visibility analysis" plugin tool was downloaded from the QGIS Plugin repository[1] to extend the core functionality of the software and conduct all viewshed analysis.

### *Study motivation*

Numerous good commercially available elevation datasets are available for usage by all spheres of society. The fact that two elevation data products from well-known interferometric SAR satellite missions (SRTM mission and TanDEM-X mission) have been post-processed to acceptable qualities and are now freely available at various levels of detail, must be intriguing, to say the least, by private and public users around the globe. Even though these datasets still contain small artefacts – such as voids, spikes and striping,

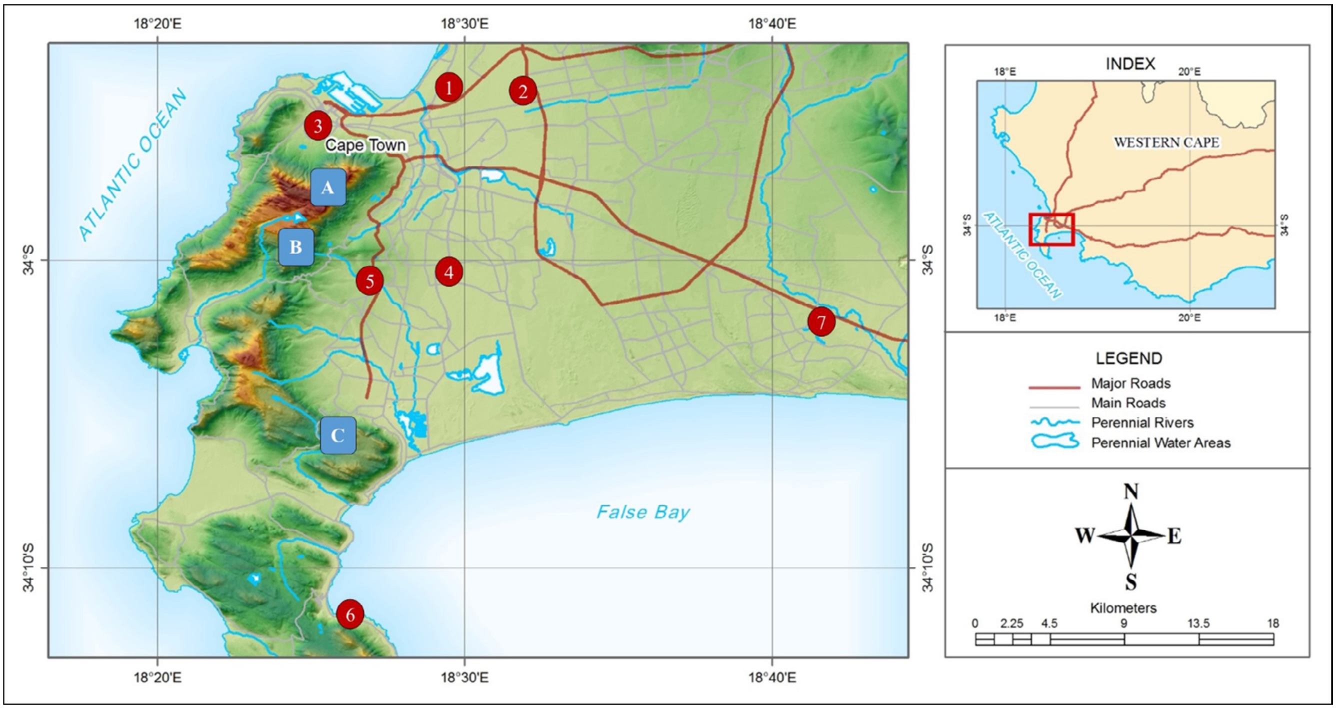



FIG. 1 - Geographical study area showing the locations of OPs (blue squares) and target points (red circles) in the Cape Town region.

among others – which need to be removed and corrected before performing 3D analyses, the usefulness thereof is of great value towards assessments of severe environmental impacts and even security on a global scale.

Even though there is a known difference on the impact that various DEM resolution accuracies have on the reliability of a viewshed analysis, it is still interesting to determine if the low resolution TDM90 DEM can compare to the well-known higher resolution SRTM30 DEM. In this study, comparisons in terms of the DEM's suitability towards producing reliable military viewshed analysis products will be analysed.

Terrain visibility plays a pivotal role towards the success of any military operation and military history shows us that battles have been won and lost due to the knowledge and successful usage of the terrain (Scott Jr, 1993; Doyle & Bennett, 2013; Knighton, 2016). Determine the suitability of the TDM90 product to deliver reliable and accurate viewshed analysis products for military operations when compared to the SRTM30 product, will prove valuable to the military forces that depend on freely available elevation data to spatially support military operations.

### *Area of interest*

The Cape Town region (South Africa) was identified as the area of interest for conducting the study (fig. 1). As part of the Cape Town region, the 1 570 km$^2$ area of interest is characterised by diverse topographical layouts, with the highest point at 1084 m. It ranges from mountainous areas with natural ecosystems to relative flat plateaus covered by a variety of settlement patterns and typical urban activities and land uses.

In the military, an observed area may be characterised by urban or rural areas, flat plains or mountainous areas and it may cover vast terrain or be limited to short range targets to observe, conceal, restricted access and provide good field of view of the surrounding terrain. These are exactly the characteristics of this area of interest.

### *Data, hardware and software*

One must consider the influence of the data and the hardware and software for determining the most suitable elevation data source to use for a viewshed analysis. It is important to use the same software on the same computer hardware and that all inputs and parameters are identical when conducting multiple viewshed analyses on the same area of operation for the purpose to determine the most suitable elevation data to use. This will ensure that comparisons can be drawn between the outputs by means of triangulation and will ease the selection process.

*Data.* A digital elevation model is a regular array of x, y and z coordinates that describes the surface of the Earth above sea level. DEMs are also known as digital height models (DHM), digital terrain models (DTMs) and digital surface models (DSMs). The term DEM is most of the time used as a generic term for a DTM and DSM (Jacobsen, 2003). However, in practice these terms are actually different products and the type of elevation data used for visibility analyses will influence the results achieved. DTMs are a broader term and include heights and elevations, but also refer to geographical elements and natural features on the surface of the Earth, such as rivers and ridges (Tighe & *alii*, 2009). Conversely, a DSM represents the Earth's surface, including all objects on it, such as the reflective surface of trees, buildings and power lines (Tighe & *alii*, 2009).

The two elevation data sources used during this study are digital surface models with the advantage that physical features on the DEM can be identified as references to target points (Tickle & *alii*, 2010). However, these reflective features can also negatively impact and impede terrain visibility (on a finer scale) by obstructing target points. The two datasets used to conduct this study were the SRTM 1 Arc-Second Global 30m Void-Filled DEM and the TerraSAR-X 90m DEM.

SRTM30. The DEM derived from NASA's Shuttle Radar Topography Mission was the first and most accurate near-global elevation model when it was released in 2000 (Luedeling & *alii*, 2007). The SRTM elevation datasets are also freely available for download at either a low ground sampling distance (GSD) of 90 m or a higher GSD of 30 m. The SRTM dataset provides good terrain coverage and comply with said specifications of providing an absolute vertical accuracy of less than 16 m and a relative vertical accuracy of less than 10 m at 90% confidence. One drawback in the use of this dataset is the voids in the SRTM elevation model, which were caused by poor radar back scattering signals and therefore no meaningful reflections were detected by the radar interferometer. However, in recent years the National Geospatial-Intelligence Agency (NGA) has edited and finished post-processing of the SRTM 1 Arc-Second (30m) Global DEM to create a void-free product. This product was made freely available on 2 January 2015 to the global community by the U.S. government for download from the U.S. Geological Survey (USGS) portal[2].

TDM30. TanDEM-X, which comprises of two twin satellites, namely TerraSAR-X (launched in 2007) and TanDEM-X (launched in 2010), are currently rated as the most accurate and precise global elevation dataset available with 12 m postings and 2 m relative height accuracy for flat terrain. Its absolute height accuracy is 1 m and the *"3D image of the Earth was completed in September 2016 and is approximately 30 times more accurate than any other global dataset"* (Burtscheidt, 2018). TanDEM-X has a GSD of 12 m (known as the WorldDEM), but reduced resolution versions of 30 m and 90 m at the equator were also created by the German Aerospace Centre (Deutsches Zentrum für Luft- und Raumfahrt DLR). On 28 September 2018, the TDM90 was release as a global dataset for scientific use and can be freely downloaded from the TanDEM-X Science Service System[3].

For this study, these two products were projected to the EPSG 32734 (WGS84/UTM34S) coordinate reference system. The projected coordinate system is a necessity for conducting a viewshed analysis, because metrics are used to calculate the analysis and therefore the coordinate reference systems must be the same for all tests and all data. This will ensure the reliability of the data results, because the same unit of measurements are utilised to represent the x, y and z-values. Utilising data that have different coordinate reference systems will negatively influence the resulting viewshed products and provide an incorrect reflection on the comparison results.

*Hardware.* Conventional hardware was used during this study, which was more than suitable to handle 3D rendering processes. Geospatial functions and tools could be used without any system failures and the same hardware was used for all processes, tests and comparisons. The hardware specifications are as follows:

a) Operating system: 64-bit with Windows 7 Professional (Service Pack 1).
b) Manufacturer: Dell.
c) Model: Optiplex 9020.
d) Processor: Intel(R) Core(TM) i5-4590 CPU @ 3.30 GHz.
e) Installed memory: 4.00 GB.

*Software.* This study utilised the FOSSGIS product, QGIS version 3.4.4 'Madeira'. All necessary plugins were downloaded from the QGIS Plugin repository[4]. FOSSGIS is becoming increasingly valuable in the international geospatial community. It consists of various tools to assist the GIS operator in performing both basic and advanced geospatial tasks. According to Steiniger & Bocher (2009), some of the most widely used FOSSGIS applications are QGIS, gvSIG, GRASS, OpenJUMP, uDIG, PostGIS, MapWindow, SAGA, WhiteBox GAT, Kosmos and TerraView (Henrico, 2016). QGIS was selected as the preferred software, because it is easily available and downloadable by means of the Internet, it is easy to install, the software can run on a variety of computer operating systems and numerous easily assessable "plugins" are available for download that provide extra functionalities (Henrico, 2016). Utilising open source software makes the study repeatable, i.e., other scientists can repeat this study and verify the results.

*Sampling locations*

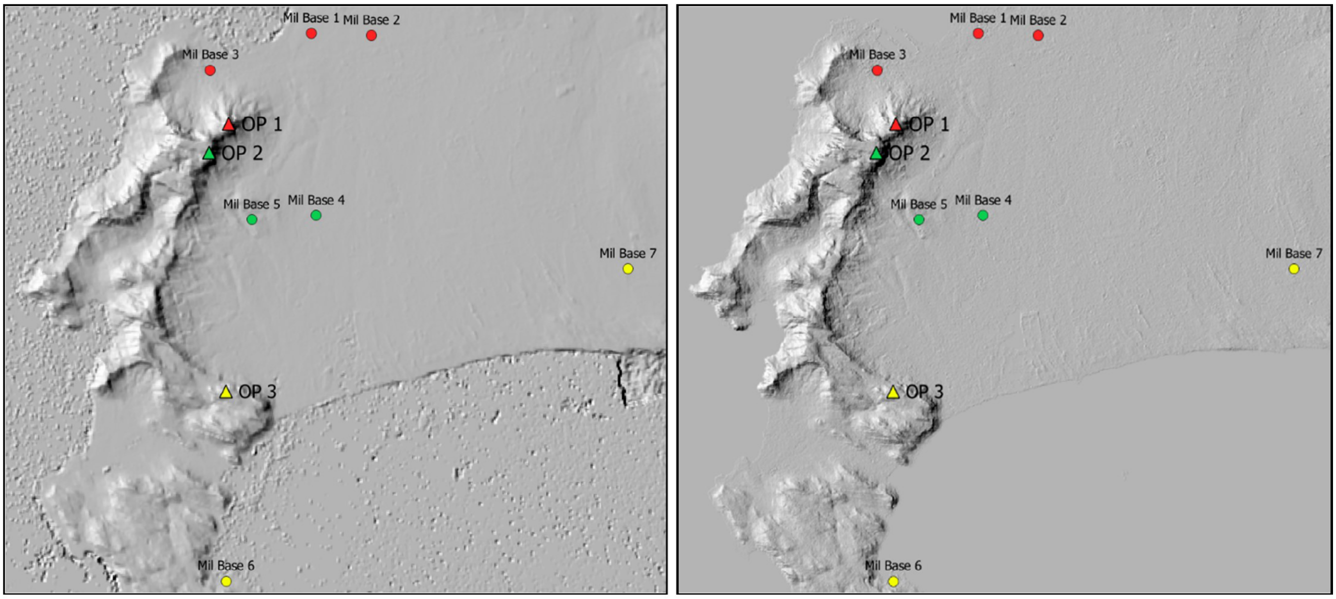
This study considered different placements of three observer points (OP) in the Cape Town region. Locations of the OPs were randomly selected to represent the best strategic positions to have a good field of view of the surrounding terrain as a military requirement for OP placements (GlobalSecurity.org, 2000; Infantry Drills, 2018). Observation points were placed on various terrain elevation locations to better compare the visibility results between the two datasets. OP 1 was placed on an elevation height of 954 m above mean sea level (MSL), OP 2 at 1083 m MSL and OP 3 at 532 m MSL. These points formed the basis for the viewshed analysis which were the nodal points from where all 'Visible' and 'Not Visible' areas were calculated and indicated.

*Tests and analysis*

This study consists of six viewshed analysis tests, one test for each of the three different OP locations using both the SRTM30 and the TDM90 products:

**SRTM30:**

a) Test 1: Utilised OP 1, which was placed at an elevation height of 954 m above mean sea level (MSL) and a search radius of 10 000 m was selected to determine if military bases 1, 2 and 3 would be visible or not from this location.




***TanDEM-X 90m DEM*** ***SRTM 30m DEM***

FIG. 2 - Locations of observation positions and military bases (Test 1 = red, Test 2 = green, and test 3 = yellow) on the two elevation sources.

b) Test 2: Utilised OP 2, which was placed at an elevation height of 1083 m MSL and a search radius of 8500 m was selected to ascertain if bases 3 and 4 would be visible or not.
c) Test 3: Utilised OP 3, which was placed at a height of 532 m MSL with a search radius of 30 000 m to establish if bases 6 and 7 would be visible or not.

**TDM90:**

a) Test 4: Utilised OP 1 and the same parameters as defined for Test 1.
b) Test 5: Utilised OP 2 and the same parameters as defined for Test 2.
c) Test 6: Utilised OP 3 and the same parameters as defined for Test 3.

For each OP location (fig. 2) a comparison was drawn between the accuracy of the visibility results achieved from using the two elevation datasets.

*Conducting the viewshed tests*

In QGIS, the "Visibility analysis" plugin toolbox allows the user to specify all the observer parameters and choose what type of output is required. Two methods for performing a viewshed analysis exist within QGIS 3.4.4:

a) The first method makes use of the visibility plugin, which is located under the Processing Toolbox. The first step for using this plugin, when performing a viewshed, is to create observer points with the create viewpoint dialogue box (*visibility analysis → create viewpoint → create viewpoint*) through loading previously defined location points that are saved as a geopackage file. Next, the viewshed dialogue box are utilised (*visibility analysis → analysis → viewshed*) and the observer points, previously created, are loaded. This method was used during this study and the parameters selected for performing the viewshed tests are described in table 2.
b) The second method consists of using the *GRASS* plugin and the *r.viewshed* module (*GRASS → Raster (r.*) → r.viewshed*) and has one dialogue box for setting all basic and advanced parameters.

RESULTS

The modelled viewshed results for each of the two datasets produced different visibility results (fig. 3).

The 'Not Visible' and 'Visible' areas were influenced by the effect the terrain elevation had on the location of each OP. There are also definite differences when comparing the visibility results between the SRTM30 and TDM90 datasets (i.e., Test 1 vs Test 4, Test 2 vs Test 5 and Test 3 vs Test 6).

Table 3 shows that the total number of cells measured in the search radiuses using the SRTM30 dataset was increasingly higher compared to the TDM90 dataset (e.g., 392 249, 283 417 and 3 530 477 compared to 43 601, 31 505 and 392 465). The viewsheds produced from using the SRTM30 dataset had a total of 88.88% more number of cells for each search radius than the TDM90 viewsheds. This was due to the differences in GSD of each dataset. The SRTM30 has a much finer resolution than the TDM90, hence the more number of cells for the SRTM30 dataset.

The 'Not Visible' and 'Visible' area coverage differed in each test for both datasets (table 3). The visibility results produced from using the TDM dataset created overestimations of the 'Not Visible' areas for both Tests 4 and 6 compared to Tests 1 and 3, but not when comparing Test 5 to Test 2. During this comparison, Test 5 shows a small, but higher 'Visible' area coverage and a small, but lower 'Not

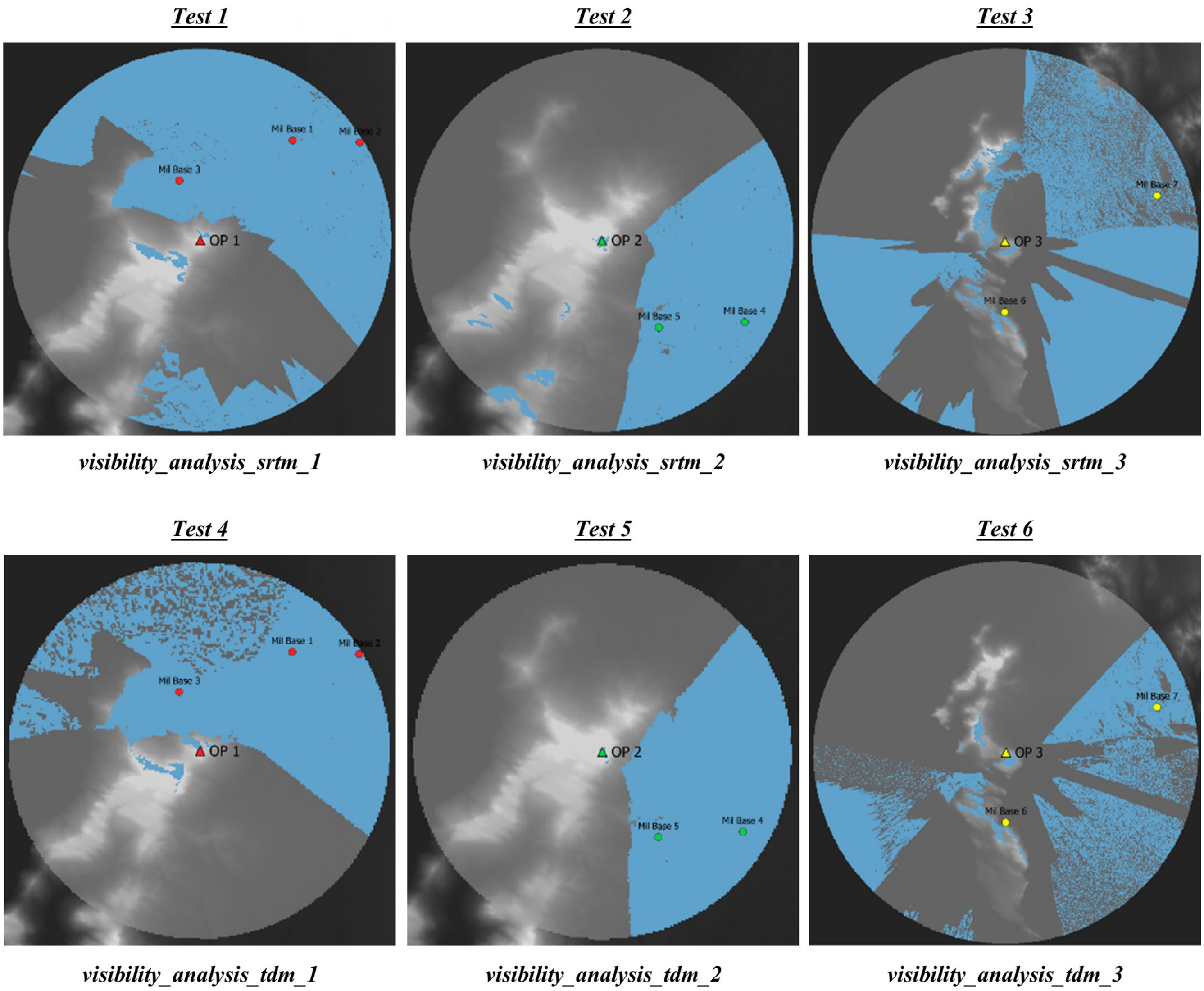



FIG. 3 - Visibility results for Tests 1-6. The transparent greys areas indicate 'Not Visible' areas and the blue areas indicate 'Visible' areas. The OPs and military bases are also indicated.

TABLE 2 - Viewshed parameters selected.

| Parameters | | SRTM 30m DEM | | | TanDEM-X 90m DEM | | |
|---|---|---|---|---|---|---|---|
| Elevation raster | | Selected raster to perform Tests 1, 2, and 3 | | | Selected raster to perform Tests 4, 5, and 6 | | |
| Output files | | visibility_analysis_srtm_1<br>visibility_analysis_srtm_2<br>visibility_analysis_srtm_3 | | | visibility_analysis_tdm_1<br>visibility_analysis_tdm_2<br>visibility_analysis_tdm_3 | | |
| Observation points | | OP 1, OP 2 and OP 3 (FIG. 2) | | | | | |
| Target points (intervisibility) | | No target points were created. However, the viewshed analysis were conducted to determine if selected military bases were visible or not from the various observation positions. | | | | | |
| Settings | Tests | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 | Test 6 |
| | Search Radius | 10 000 m | 8500 m | 30 000 m | 10 000 m | 8500 m | 30 000 m |
| | OP Height | 1.75 m (average eye-level height of a man standing) | | | | | |
| Output | | The *'Binary viewshed'* output was selected | | | | | |
| Options | | The *'Use earth curvature'* option was selected with a 0.13 Atmospheric refraction and the Precision was *'Fine'* | | | | | |

Visible' area coverage than Test 2. The percentage area coverage for these two tests are very similar in what can be seen and not seen from this observation position.

TABLE 3 - Area coverage comparison of viewshed results.

| SRTM30 viewshed tests | | | |
|---|---|---|---|
| Measurements | Test 1 | Test 2 | Test 3 |
| *Number of cells in viewshed search radius (Count)* | 392 249 | 283 417 | 3 530 477 |
| *Number of cells visible (Count)* | 200 737 | 79 585 | 1 544 162 |
| *Number of cells not visible (Count)* | 191 512 | 203 832 | 1 986 315 |
| ***Visible Area Coverage (%)*** | **51.18** | **28.08** | **43.74** |
| ***Not Visible Area Coverage (%)*** | **48.82** | **71.92** | **56.26** |
| TDM90 viewshed tests | | | |
| Measurements | Test 4 | Test 5 | Test 6 |
| *Number of cells in viewshed search radius (Count)* | 43 601 | 31 505 | 392 465 |
| *Number of cells visible (Count)* | 18 204 | 9 681 | 94 566 |
| *Number of cells not visible (Count)* | 25 397 | 21 824 | 297 899 |
| ***Visible Area Coverage (%)*** | **41.75** | **30.73** | **24.10** |
| ***Not Visible Area Coverage (%)*** | **58.25** | **69.27** | **75.90** |

One interesting observation, which is evident from studying the two datasets is the noisy areas (artefacts) that were identified by the TDM90 as either not visible or visible areas. These artefacts were caused by the radar backscattering properties from the disturbed sea surface and are characteristics of the non-edited TerraSAR-X 90m DEM product.

## DISCUSSION

It was expected that the SRTM30 DEM would produce higher visibility analysis accuracies for all three OPs in comparison to the TDM90 DEM. It was therefore no surprise to notice the 'Visible' and 'Not Visible' differences highlighted by fig. 3, which were mainly caused by the finer GSD of the SRTM30 DEM.

There were definite differences in the visibility results measured from both DEMs, but also similarities towards the results measured. In general, both DEMs considered mostly the same areas as being 'Visible' or 'Not Visible' and in comparison, there was not one test where the results were highly skewed:

a) Test 1 vs Test 4: Shows an overestimation or underestimation difference of 9.43% of 'Visible' and 'Not Visible' areas.
b) Test 2 vs Test 5: Shows an overestimation or underestimation difference of 2.65% of 'Visible' and 'Not Visible' areas.
c) Test 3 vs Test 6: Shows an overestimation or underestimation difference of 19.64% of 'Visible' and 'Not Visible' areas.

It is evident that the differences in 'Visible' and 'Not Visible' areas are small considering the difference in GSD between the two datasets used to conduct this study. These statistics also indicate that the smaller the radius in analysis is, the smaller the differences are and the differences progressively increase as the radiuses increase:

a) 8 500m radius of analysis: Tests 2 vs Test 5 produced a 2.65% visibility difference.
b) 10 000m radius of analysis: Tests 1 vs Test 4 produced on a 9.43% visibility difference.
c) 30 000m radius of analysis: Tests 3 vs Tests 6 produced a visibility difference of 19.64%.

This study entailed the use of a basic viewshed function to determine the differences in terrain visibility, indicated as being either 'Visible' or 'Not Visible' as observed from the various OPs. This relates closely to a typical military viewshed requirement, which entails the placement of an observation point (or multiple points) to estimate the visible area towards a specific target/s (e.g., enemy base), simulating the placement of a military observer to gather intelligence about enemy force strength and movement. In this case, the low resolution TDM90 DEM product, when compared to the higher resolution SRTM30 DEM product, was used to determine the DEMs' suitability to conduct a visibility analysis for a military operation. Considering the above mentioned, it is interesting to note that all military bases were either 'Visible' or 'Not Visible' for all tests and instances for both DEM products.

The fact that two distinctly different DEMs were used to conduct this study, characterised by their different resolutions, military commanders can use these DEMs to conduct viewshed analyses to assist in his or her decision-making. It is imperative for a military commander – as well as any user of digital elevation data – to recognise the fact that digital elevation data do have limitations and consist of inherent errors (Tickle & *alii*, 2010). Users should be aware of these errors, especially when decisions are based on information derived from specific digital elevation data that are used *"for finer scale applications requiring accuracy less than the specified vertical accuracy"* (Tickle & *alii*, 2010). It is therefore imperative to note that higher resolution DEMs would produce better accuracy results and a more reliable visibility representation of the terrain that will have a desirable effect on the successful execution of not only a military operation, but also on any 3D analysis required task.

## CONCLUSION

In the military, it is essential for the commander to have access to all available information to make accurate and informed decisions that could influence the outcome of any military operation. In this regard, GIS and the role it plays in producing geospatial products for military purposes provides an important planning tool to the military commander. However, the geospatial information provided should be accurate, complete and reliant.

This study compared the visibility results of two distinct global DEMs that are freely available. The TanDEM-X 90m dataset was released in September 2018 and is still fairly new with regards to its capabilities and reliable usages to the geospatial communities, but the SRTM 30m dataset, which was globally released for public use in January 2015, have been tried, tested and used in all spheres amongst the geospatial communities. This study was conducted to determine the suitability of the lower resolution TDM90 dataset to calculate a viewshed analysis for military operations, when compared to the higher resolution SRTM30 dataset.

As was expected, the finer spatial resolution SRTM30 dataset produced a much better visibility representation of the terrain, because more terrain obstacles could be considered during the analysis than the TDM90 dataset, which either underestimated or overestimated the visibility of the terrain, due to its coarse GSD. It is evident that the artefacts that are embedded in the non-edited TanDEM-X 90m dataset also played a role in these area estimations.

From the above statements, it can be argued that the TDM90 will not be a suitable elevation dataset to calculate a visibility analysis for military operations. However, the results of this study confirmed the opposite. In the military, elevation datasets can be used to produce various visibility analysis products in support of a military operation, as were described in table 1. Some of these products might only require the use of a low resolution elevation dataset and others will require a high resolution dataset. This study had the limitation that it only tested one basic visibility analysis military function, with restricted parameters and using only two coarse elevation datasets. It can therefore not be expected that the same results and comparison differences will be achieved when different parameters, datasets or even topographic areas are used.

However, this study proved that the TDM90 dataset compared well to the SRTM30 dataset when only an observation to a specific target is required in the Cape Town region. All military bases were either visible or not visible from the different OP positions using either the SRTM30 or the TDM90 dataset. The TanDEM-X 90m DEM is therefore suitable when performing viewshed analysis for creating a basic military product, such as determining the possible placement of observation positions to gather intelligence about enemy force strength and movement.

However, the TanDEM-X 90m DEM will not be suitable when more advanced and higher accuracy is required for military operations. Such examples, include: determining a helicopter landing zone within a *'hot zone'*, revealing or concealing friendly or enemy force movements and determining accurate placement of observations positions necessary for correcting aim of indirect weapon fire.

It is also important to note that even though the SRTM30 dataset has a finer resolution than the TDM90, both datasets consists of fairly coarse resolutions limiting their ability to be used for advanced military applications. For the military commander this can be troublesome and negatively influence his planning. Consequently, higher accurate and resolution datasets (e.g., WorldDEM 12m or even LiDAR 5m or 1m elevation data) should be considered when a viewshed analysis is required in support of military operations that require highly accurate and reliable viewshed product. Nonetheless, the readily available datasets used during this study, especially the SRTM30 dataset, can provide a general and fair model of terrain visibility. These datasets consist of artefacts that negatively influence the reliability and accuracy of the terrain model and should be handled with care when they are used by a military commander in support of military operations.

*Notes*

[1] https://qgis.org/en/site/forusers/download.html
[2] http://earthexplorer.usgs.gov/
[3] https://tandemx-science.dlr.de/
[4] https://plugins.qgis.org/plugins/

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*(Ms. received 30 January 2020, accepted 28 December 2020)*

Edizioni ETS
Palazzo Roncioni - Lungarno Mediceo, 16, I-56127 Pisa
info@edizioniets.com - www.edizioniets.com
Finito di stampare nel mese di dicembre 2020