Positional accuracy of the drainage networks extracted from ASTER and SRTM for the Gorongosa National Park region - Comparative analysis

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Abstract: Digital Elevation Models (DEMs) are useful for a great quantity and diversity of applications, namely for hydrologic studies that require the identification of hydrographic basins and water lines. Basins' boundaries and the hydrographic network can be automatically extracted from DEMs, therefore their accuracy is influenced by the DEMs accuracy. Hence, it is important to control the influence of DEMs errors over the features extracted from them, since differences may be found that influence the basins' management and/or the modeling of other phenomena.

In this scope, the purpose of the developed work is to evaluate the positional accuracy of the hydrographic network obtained for the Gorongosa National Park (GNP) in Mozambique, using the Advanced Spaceborn Thermal Emission and Reflection Radiometer (ASTER) and the Shuttle Radar Topographic Mission (SRTM) DEMs, aiming to discover which one allows the generation of a network closer to the actual localization of the existing water lines.

The calculation of the distance between the water lines extracted from the two DEMs and lines manually digitized over an IKONOS and a SPOT satellite images show that, using two different region delimitation approaches, both the mean distance (238m for ASTER vs. 187.64m for SRTM when the first approach is used and 146.65m for ASTER vs. 133.34m for SRTM using the second) and the standard deviation (339.59m for ASTER vs. 318.29m for SRTM and 132.12m for ASTER vs. 128.09m for SRTM) values are higher when the water lines are extracted from ASTER. Therefore, the conclusion that the SRTM allows the extraction of water lines, in the GNP, with greater positional accuracy than the ASTER has been reached.

1. Introduction

DEMs are representations of the ground's surface in a raster format, where to each cell an elevation value is given (El-Sheimy *et al.*, 2005). The DEMs allow the modelling, analysis and interpretation of the ground's morphology. Their accuracy is important for a great number of geoscientific applications, such as risk prevention (e.g. floods, fires, landslides), erosion monitoring of geomorphologic units, modelling of drainage networks or environmental impact studies (e.g. El-Sheimy *et al.*, 2005; Konstantinos and Antonis, 2004). These models can be generated using data obtained from several sources, namely field data collected with global navigation satellite system (GNSS) receivers, data from topographic maps, aerial photography or satellite images (e.g. El-Sheimy *et al.*, 2005; Konstantinos and Antonis, 2004). There are DEMs that represent a major percentage of the Earth's surface, which are called Global Digital Elevation Models (GDEM). Despite the advantage of representing most of the continental surface, the GDEMs have relatively low spatial resolutions and vertical accuracies (Tighe and Chamberlain, 2009). Also, the vertical accuracy of a DEM is not homogeneous all over the surface it represents. Such properties may vary with the terrain slope or with the land cover classes (Tighe and Chamberlain, 2009).

This work aims to determine which of two GDEMs obtained via satellite data, the Advanced Spaceborn Thermal Emission and Reflection Radiometer (ASTER) and the Shuttle Radar Topographic Mission (SRTM), enable the generation of water lines with greater positional accuracy in the region of the Gorongosa National Park (GNP) in Mozambique. In order to reach this objective, the position of the water lines generated from each GDEM were compared with the water lines digitized manually using the software ArcGIS from satellite images available within the software. These can be IKONOS or SPOT images, depending on the region.

2. Characteristics of the GDEM

Table 1 shows some characteristics of the two GDEM used, namely the SRTM and the ASTER. In the following subsections, more details about these models are presented.

Table 1 – Information concerning the SRTM and ASTER GDEMs (Tighe and Chamberlain, 2009). The indicated vertical accuracy of the models corresponds to the Root-Mean-Square Error (RMSE)

GDEM	Source	Aquisition Method	Ground Sampling Distance (GSD)	Vertical Accuracy (RMSE)
SRTM	NASA, NGA	Interferometry	90 m	16 m
ASTER	NASA, METI	Photogrammetry	30 m	20 m

2.1 Shuttle Radar Topographic Mission (SRTM)

The SRTM is a cooperative effort between the National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA). Its' data was collected aboard the Space Shuttle Endeavour during the mission STS-99, between February 11 and 22, 2000 (NASA, 2009). The SRTM dataset was obtained from raw radar echoes transformed into DEMs. The use of radar has the advantages of functioning day and night, making data collection possible regardless the existence of clouds, with little or no impact in the positional quality of this data (El-Sheimy *et al.*, 2005).

This model covers the Earth's landmass between 60°N and 56°S latitudes, with a ground sampling distance of 1 arc second (30m) in the United States area and 3 arc seconds (90m) in the remaining covered. The elevations of this GDEM were calculated relatively to the GRS80 ellipsoid (Tighe and Chamberlain, 2009; NASA, 2009).

Since the SRTM's data acquisition method is the radio interferometry, and radio waves' penetration differ for different surface element, the land cover classes will influence the accuracy of this DEM (Tighe and Chamberlain, 2009). As far as this work is concerned, the influence of the land cover classes over this GDEM's vertical accuracy in the park's area was not considered.

2.2 Advanced Spaceborn Thermal Emission and Reflection Radiometer (ASTER)

The ASTER is an advanced multispectral imager launched by NASA in collaboration with the Japanese Ministry of Economy, Trade and Industry (METI), on board of the Terra spacecraft, on the 18th of December, 1999.

ASTER covers a wide spectral region, with 14 bands, from the visible region to the thermal infrared. The images are used to create, by photogrammetric techniques (stereo-correlation), a global digital elevation model (GDEM) that covers the Earth's landmass between 84°N and 84°S latitudes with a ground sampling distance of 1 arc second (30m) for all regions, offering greater coverage

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and global ground sampling distance than the SRTM (Tighe and Chamberlain, 2009; Konstantinos and Antonis, 2004). Like the SRTM, this GDEM's elevations were calculated relatively to the GRS80 ellipsoid.

3. Data and Study Area

The study area selected for this research is the GNP in Mozambique, located in the province of Sofala, in the center of the country.

The region of the GNP selected for this study does not include the Gorongosa mountain region and is limited in the North by Nhandugue river, in the South by Pungué river, and is located approximately between 34º04'52.96''E and 34º48'36.372''E longitudes and between 18º21'01.52''S e 19º04'56.91''S latitudes, occupying an area of approximately 4000 km^2 (Figure 1).

The study area is characterized by a tropical savannah climate, according to Köppen's classification (Tinley, 1977; Arvidsson, 2010) and can be divided in three morphological units (Figure 2):

–   The great Rift valley, with 40 km of width, occupying great part of the study area and ranging from 15 to 80 meters above the average sea level.

–   East of the Rift valley the Cheringoma plateau is formed, reaching an elevation of about 300 meters above the average sea level.

–   The West of the Rift valley is characterized by the Midlands, that elevates approximately 400 meters above the average sea level.
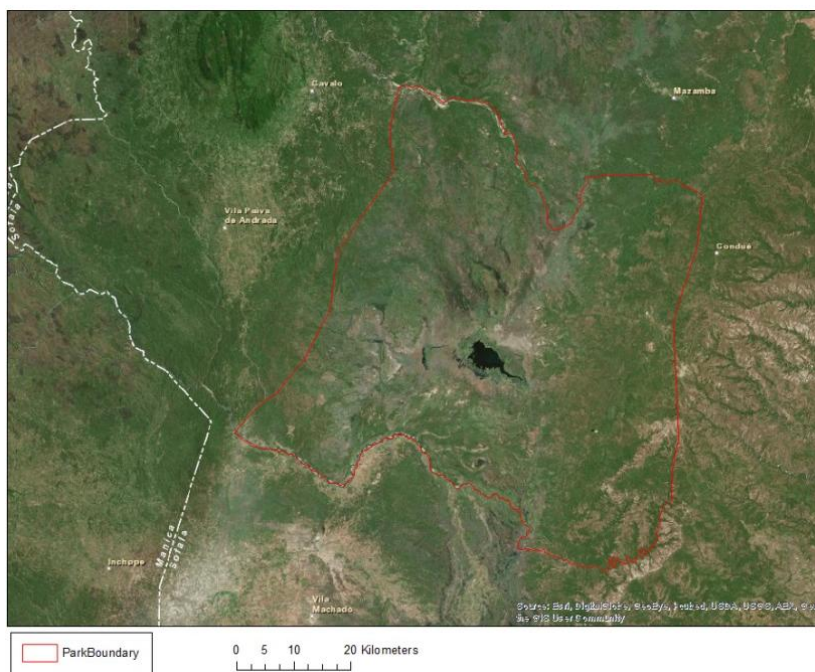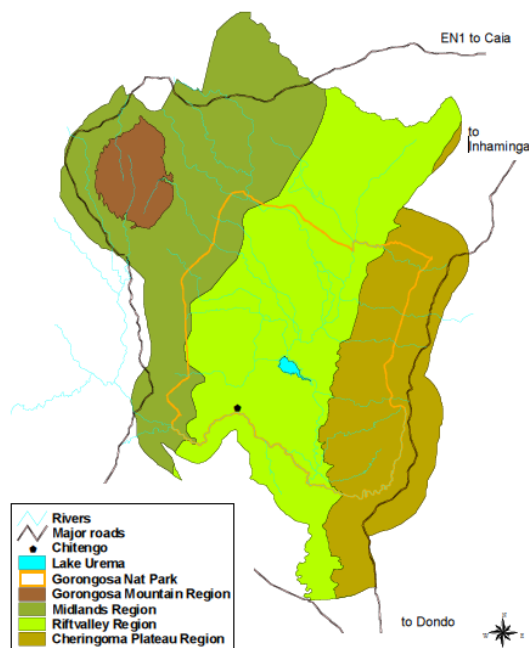

Figure 1 – Study area

Figure 2 – Morphological Units of the GNP
(Stalmans and Beilfuss, 2008)

The data used for the study area are extracts from the ASTER and SRTM GDEMs (Figure 3), available in U.S. Geological Survey and NASA websites, respectively, and satellite images available in ArcGIS software as basemap.
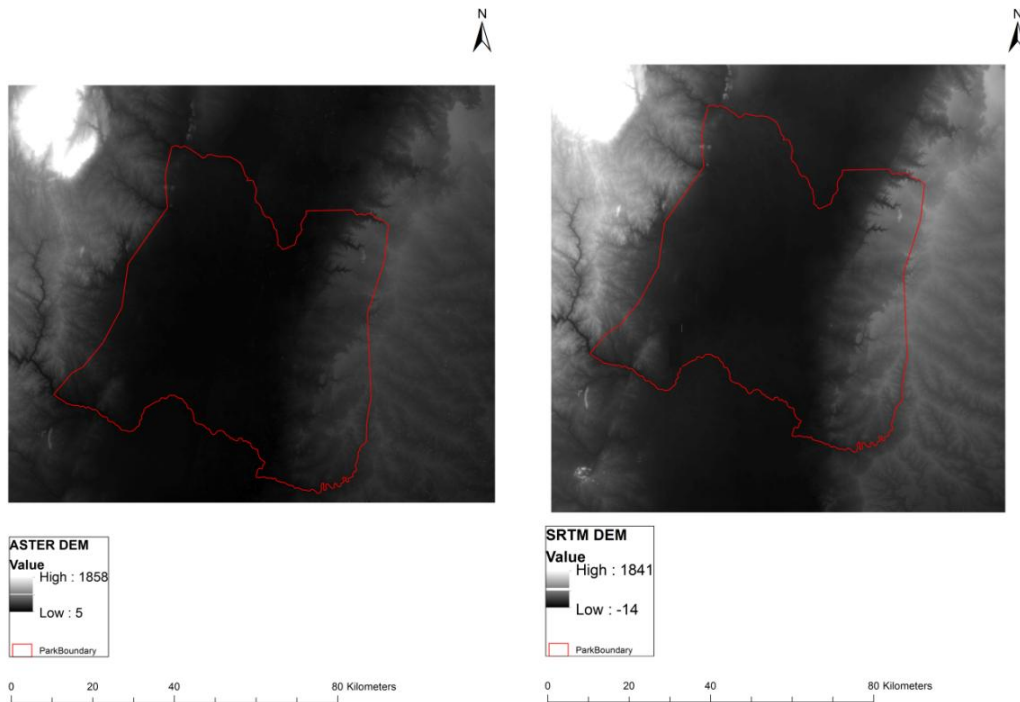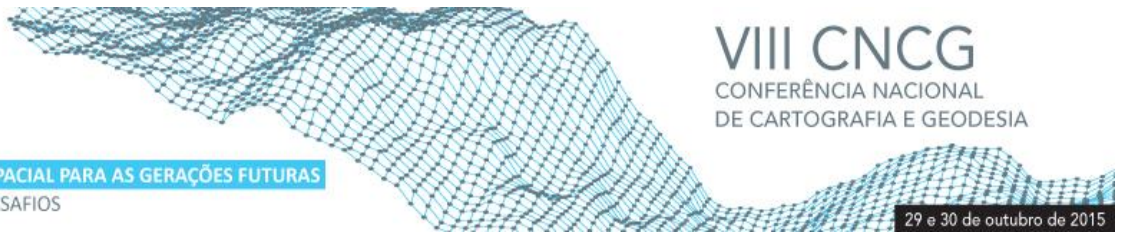
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Figure 3. Extracts from the ASTER (left) and SRTM (right) GDEMs (values in meters)

4. Methodology

The used methodology consisted in the automatic generation of water lines inside the study area from the two GDEMs using the tools available in the software ArcGIS, which generate the water lines in a raster format. Using the IKONOS and SPOT images available in ArcGIS as a basemap, the water lines that could be visually identified in them were manually digitized. Within the study area the IKONOS and SPOT images had distinct spatial resolutions, of 1 m and 2.5 m respectively, and a somewhat low image quality on the 2.5 meters resolution areas, which brought some difficulties to the digitizing process (Figure 4). However, since the ASTER and the SRTM GDEMs have a much lower spatial resolution, with a GSD of 30 m and 90 m respectively, the difference in the images' resolution will not affect this work's accuracy. The digitized water lines and the ones extracted from the DEMs can be seen in Figure 5.
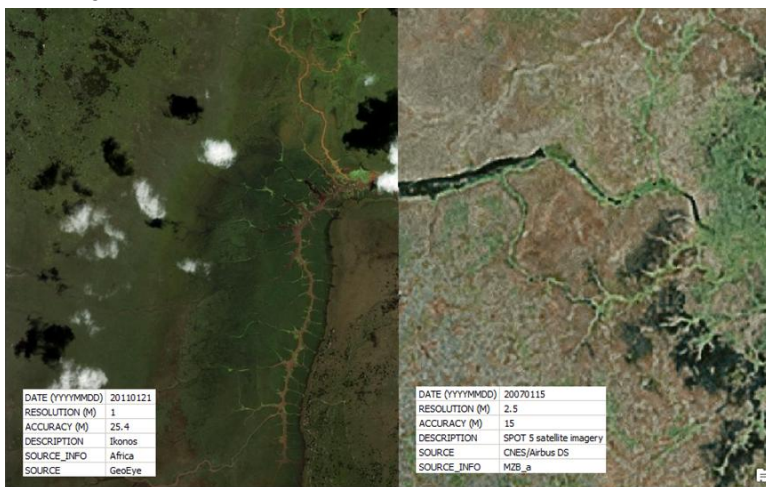

Figure 4 – Basemap images with different spatial resolutions in the study area
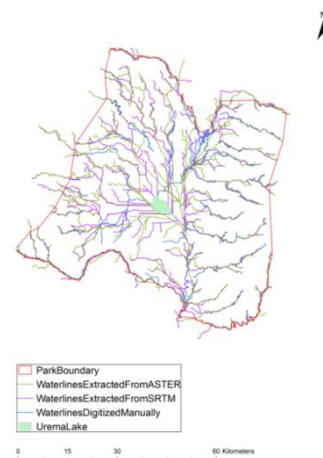

Figure 5 – Water lines extracted from both GDEMs and water lines manually digitized

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To evaluate the positional accuracy of the hydrographic networks extracted from both GDEMs, they were converted from raster to point format. Then, the distance between each point and the closest water line manually digitized was calculated. This distance is the shortest of the distances obtained considering the length of a segment passing through the point and perpendicular to the line segments of the reference water lines and the length of the line segment that connects the point to the closest reference water line vertex.

Due to the small number of water lines that could be visually identified in the images and therefore digitized, and in some cases the great distance between the position of the extracted water lines and the digitized ones, to exclude from the results errors that could be originated from the association of lines that do not correspond to the same water line, the area inside which the distances were calculated was limited by two approaches. In the first approach, some small regions were delimited, inside which the water lines extracted from both GDEMs were visually closer to the digitized ones (Figure 6). In the second approach, a 500 meter buffer around the digitized water lines was created (Figure 7). The distance between water lines (extracted and digitized) was only calculated for the lines contained inside the regions delimited by these approaches
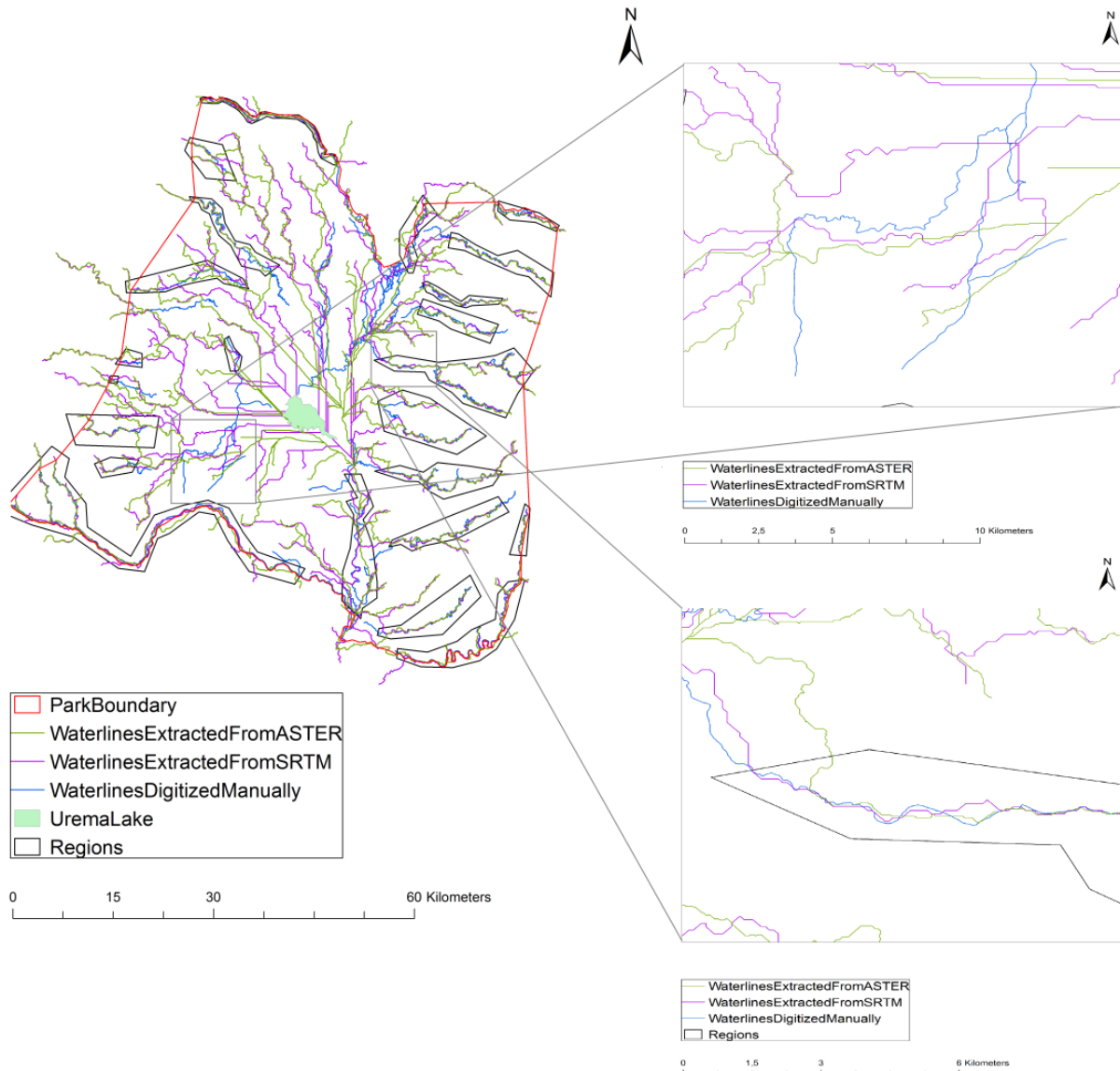

Figure 6 – Regions inside which the distances were calculated (Left); Detail of a zone where the distances will not be calculated due to the distances between extracted and digitized water lines (Top-right); Detail of a region where distances will be calculated (Bottom-right)
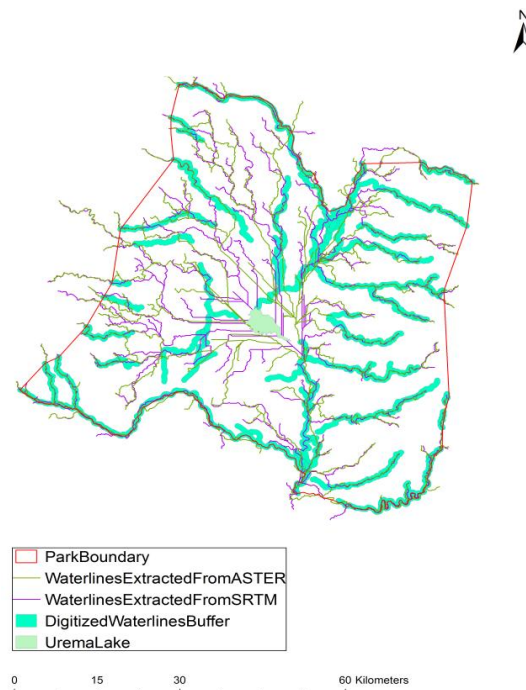
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Figure 7 – Buffers around the digitized water lines

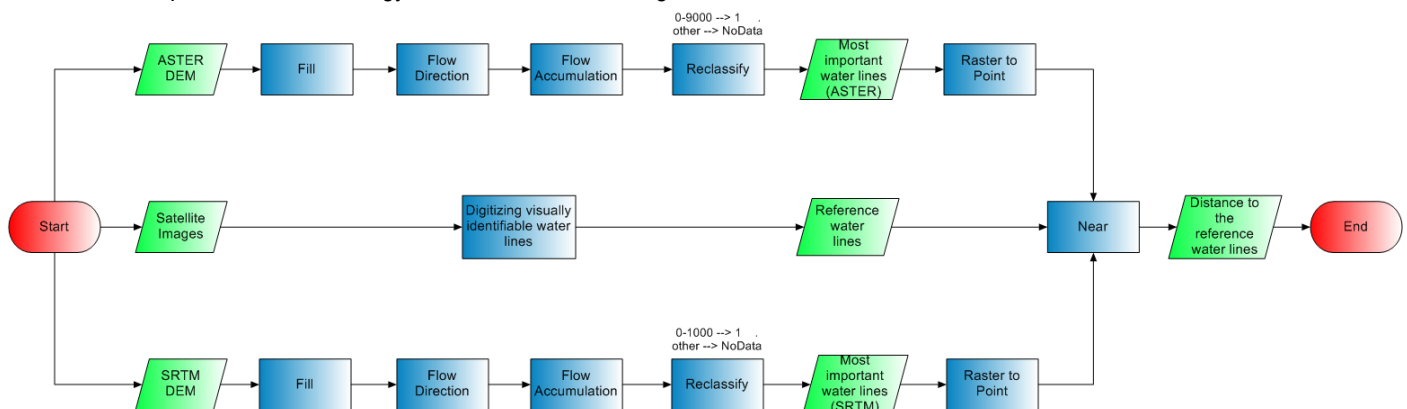The several steps of the methodology used can be seen in Figure 8.

Figure 8 – Methodology and ArcGIS tools used

5. Results

Table 2 shows the obtained results relative to the distances between the points of the water lines extracted from both GDEMs and the digitized water lines, where the position of the latter was considered as reference. The results show that, despite the region delimitation approach, the values of both the mean distance and the standard deviation between extracted and reference water lines are smaller when the water lines are extracted from the SRTM GDEM. For the mean distance, using the first delimitation approach, the values of 187.64m for SRTM vs. 238.97m for ASTER were obtained, while using the second delimitation approach the results are 133.34m for SRTM vs. 146.65m for ASTER. The standard deviation using the first delimitation approach is 318.29m for SRTM vs. 339.59m for ASTER, while using the second delimitation approach we have 128.09m for SRTM vs. 132.12m for ASTER.

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Table 2 – Analysis in the distance between water lines extracted from the GDEMs and water lines digitized from the satellite images

	Inside the Delimited Regions		Inside the Buffer	
GDEM	ASTER (m)	SRTM (m)	ASTER (m)	SRTM (m)
Minimum Distance	0.00	0.14	0.00	0.14
Maximum Distance	2774.67	2719.22	499.99	499.91
Mean Distance	238.97	187.64	146.65	133.34
Standard Deviation	339.59	318.29	132.12	128.09

Figures 9 and 10 represent some of the differences found between the two GDEMs, respectively for the slope and elevation. Significant differences can be seen in the images, which contribute to the differences found between the extracted water lines. In what concerns the slope, the data extracted from ASTER showed to have differences to the data extracted from SRTM between +57.38° and -29.40°. The altitude values extracted from those GDEMs also vary a significant amount, being in some areas 132 m higher in the ASTER and in others 120 m higher in the SRTM.
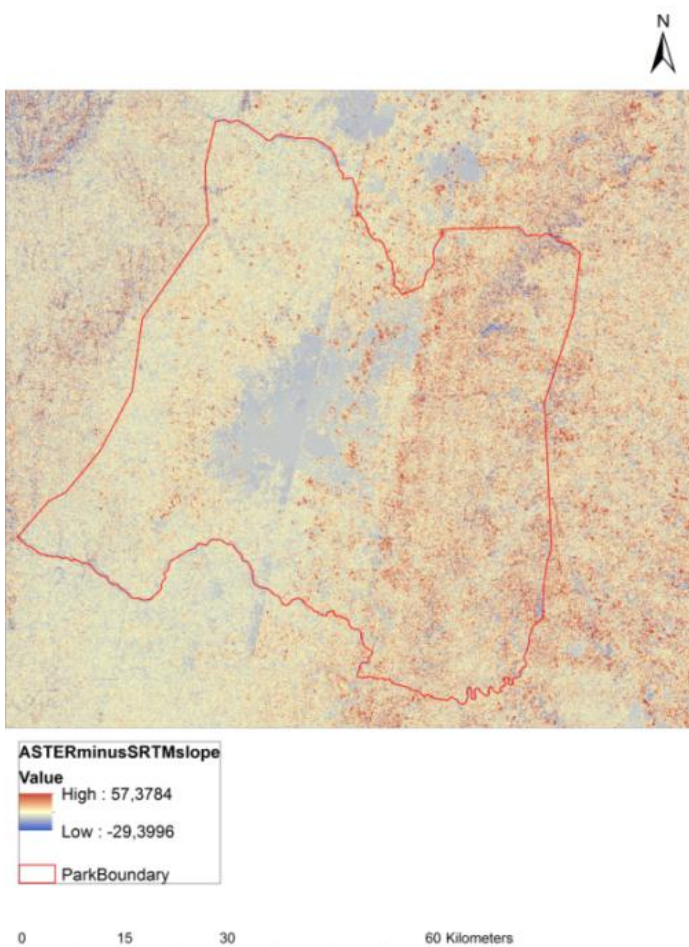

ASTERminusSRTMslope
Value
High : 57,3784
Low : -29,3996
ParkBoundary

0   15   30   60 Kilometers

Figure 9 – Difference of slopes between the ASTER and the SRTM models (values in degrees)

ASTERminusSRTM
Value
High : 132
Low : -120
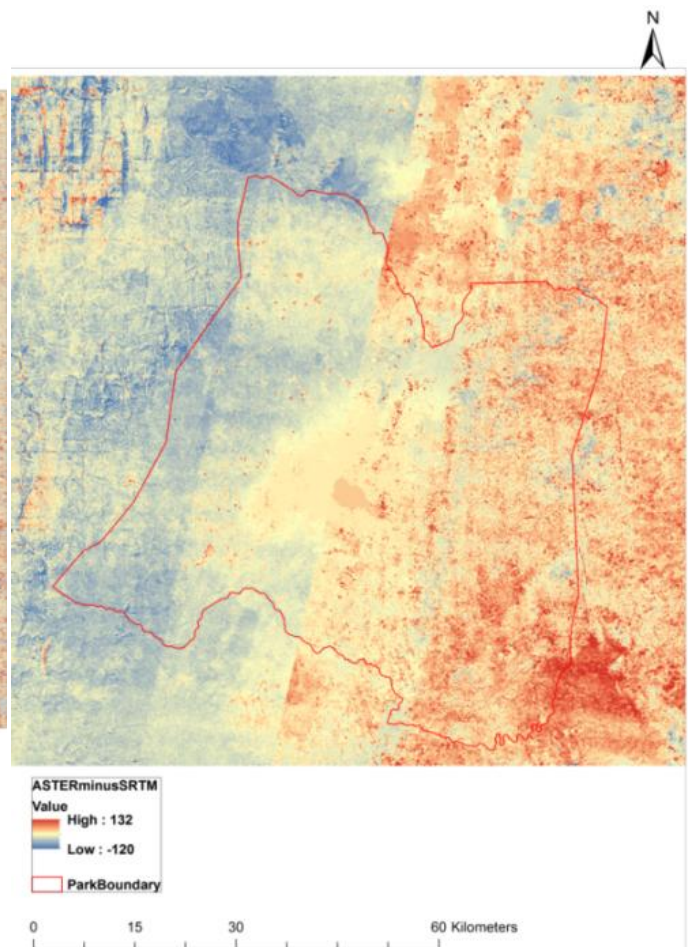ParkBoundary

0   15   30   60 Kilometers

Figure 10 – Difference of altitudes between the ASTER and the SRTM models (values in meters)

6. Conclusions

The results show that, despite the lower spatial resolution, the SRTM model offers greater accuracy in the position of the extracted water lines.

In the Urema lake region, a lack of accuracy in the position of the water lines obtained from both DEMs may be seen. The main reason for this lack of accuracy is the fact that the terrain slope in this region of the study area is very low and therefore small variations in the elevation have a large influence in the water lines' position.

Even though the digitalization of water lines that can be visually identified in the satellite images is not error-free, mainly in the regions where the spatial resolution of the images is lower, since the image's quality didn't allow their clear identification and distinction, for example, from roads, the authors consider that the consistency of the results are a good indicator that more accurate water lines can be obtained from the SRTM GDEM.

A more extensive analysis may be done in the future, using additional information about water lines available for the region or extracted from multispectral imagery, to confirm these preliminary results.

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