USING GIS IN THE SEARCH FOR SUITABLE SITES FOR THE IMPLEMENTATION OF FOG WATER COLLECTION SYSTEMS IN SOUTH AFRICA

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Abstract
Classified as a dry country and with most exploitable water sources already under tremendous strain, South Africa is under increasing pressure to sustain its expanding economy and growing population. Precipitation is unevenly distributed and available water sources are under the added impediments of pollution, contamination and over exploitation. Provision of safe drinking water to communities in mountainous and remote rural areas is a real concern. Schools in these areas often do not have reliable or safe water sources on the premises. This is a dire situation that negatively impacts on the lives of up to two million children on a daily basis.

Fog collection has been proved to provide a viable source of good quality water in many arid regions of the world. The overall purpose of this research is to examine the capability of Geographic Information Systems (GIS) as a tool to identify appropriate areas where communities in South Africa may benefit from the collection of water from fog. The rationale is to use the knowledge obtained from completed international and local research to create a GIS methodology that will help to identify areas that adhere to an established set of criteria.

Records show that, within South Africa, the highest fog frequencies are mostly located along the very dry West Coast and in mountainous regions in the eastern and southern parts of the country, which experience the influx of maritime air from the coast. In order to determine the slopes that are suitable for receiving fog bearing winds, a raster based Digital Elevation Model (DEM) is employed to determine the preferable elevation zones as well as the suitable slope aspects. Subsequently, topography profiling provides a more detailed investigation of the selected areas.

Initial research confirms that GIS software provide valuable tools for the classification of suitable slope categories in mountainous areas in South Africa and it is demonstrated that Geographic Information Systems can be successfully applied in the identification of potential recipients of fog-net water collection systems.

Introduction
South Africa is under increasing pressure to sustain its expanding economy and growing population. Water supply and precipitation are unevenly distributed and all available

water sources are under tremendous pressure (DEAT, 2006). As several studies established that fog water collection can be successful in some fog prone regions, this may offer some respite (Olivier & Rautenbach, 2002).

In the early 1990s a Fog Water Collection Project, partly funded by the Water Research Commission (WRC project K5/671), was launched in South Africa by a team of researchers from several South African universities. The project targeted the West Coast as well as the mountainous areas of the Limpopo and Mpumalanga provinces. An interpolation of mean annual fog day frequencies at 268 weather stations was displayed on a map of fog frequencies in South Africa. The project also resulted in the construction of a successful fog collection system at the Tshanova Primary School in the Limpopo Province (Olivier & van Heerden, 1999).

The WRC study concluded that well placed and securely constructed fog nets could have considerable benefits for remote communities.

Objectives

The overall purpose of this study was to examine the competence of the surface analysis tools available in Geographic Information System (GIS) software in the identification of appropriate areas for fog collection systems.

In 2006 a preliminary study showed that more than 90 of the schools in the Limpopo Province that experience a serious water shortage are situated in fog prone areas. The results of this study were then refined and used to support the selection of a school which could benefit from a University of Pretoria Community Project which included the construction of a fog collection system in the Limpopo province. In 2008 and 2009 two further studies were conducted at different scales and resolution at specific locations along the east and west coast respectively. Due to vast differences in terrain, atmospheric circulation, data availability, application specific requirements and time constraints, the analysis methodologies, although similar, were adapted to the suite specific criteria and requirements in each instance. The three study areas and specific locations are depicted in Figure 1.

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Figure 1:

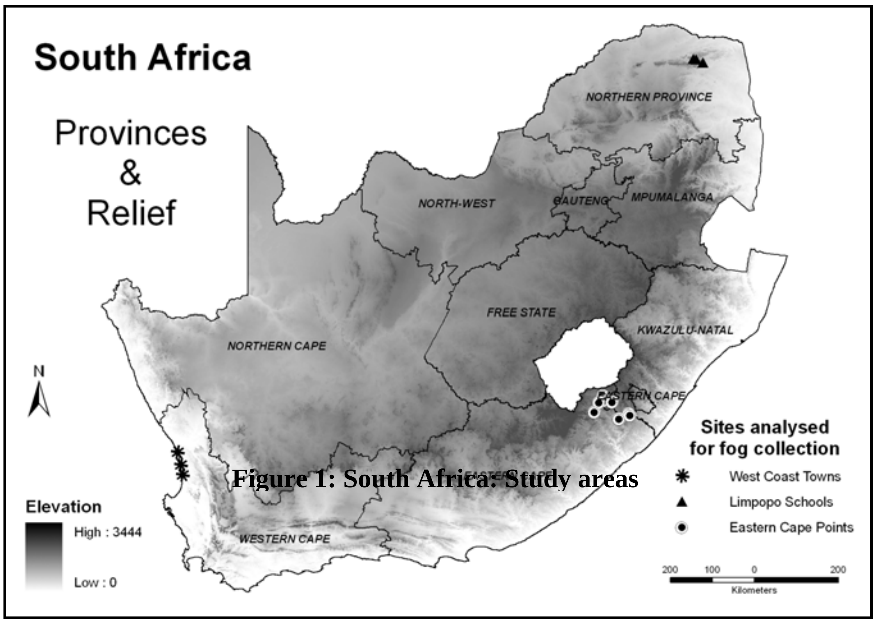


Figure 1: South Africa: Study areas

Methodology

The rationale used is to utilize the knowledge obtained from other completed research projects to create a GIS methodology that will identify areas suitable for the erection of fog collection systems.

By using spatial analysis tools such as *reclass* and surface *aspect*, preferable elevation zones as well as suitable slope aspects are identified. These are then combined to demarcate suitable areas. The results can be applied to further GIS analysis procedures in line with the criteria and particular conditions of the study area. Topography profiling is applied as an added source of investigation to support or discard selected sites for fog collection. Results are tested against existing pilot sites and information obtained from site visits.

Case study 1: Fog water to schools in the Limpopo province

The Limpopo Province is situated in the north eastern part of South Africa. The province is heavily populated and one of the poorest areas in the country. The region experiences frequent droughts and has a definite wet and dry season. A significant part of the geographical area of the Limpopo Province falls within mountainous areas prone to fog conditions such as the Soutpansberg and the mountains forming the eastern escarpment of the country (Olivier & Rautenbach, 2002).

There are about 4260 schools in the Limpopo Province of which 1567 (36.8%) has no reliable water source on the premises. This is a dire situation that affects more than 54 000 children on a daily bases. Schools that do not have a safe reliable water source were targeted in this study. Slopes that are facing fog-bearing winds from the Indian Ocean in areas between 800m and 1400m above sea level were specified as suitable, whilst areas above 1400m above sea level were perceived as highly suitable. It was anticipated however that not many schools will be situated at such high altitudes. Because of possible maintenance issues a maximum distance of 500m between the school and the fog collection system was allowed for the piping of water.

A raster based 90-meter Digital Elevation Model (DEM) was used for the slope analysis. Census data obtained from the Municipal Demarcation board regarding all schools in South Africa were used to identify all the Limpopo schools without a reliable water source. River catchments on the coastal side of the mountains, facing incoming maritime air, were manually selected to further focus the study area. All data were obtained in digital format and transferred electronically. Data compatibility was verified after each addition of a dataset to the project.

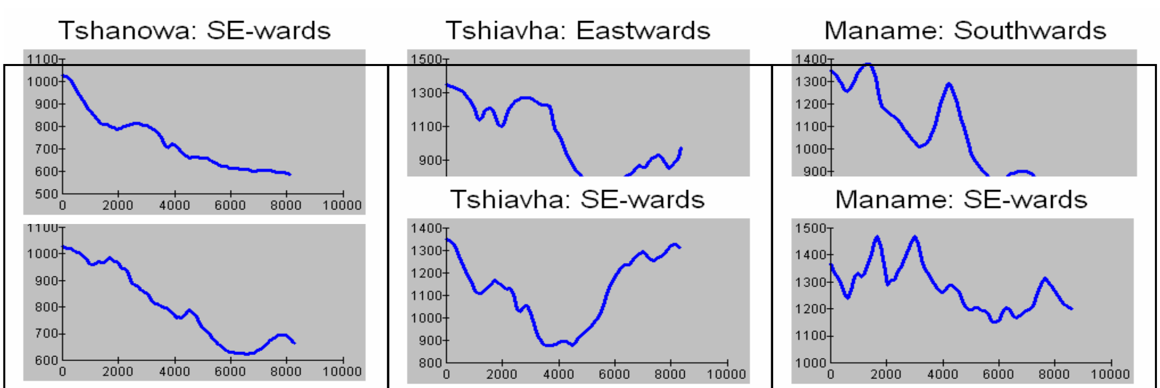
Elevation data were reclassified into height categories as specified by the mentioned project criteria and slope aspects were reclassified to select those facing the influx of maritime air. Raster maths was used to combine the two “suitability” data sets i.e. suitable elevations and suitable aspects. GeoTiff images of the relevant 1:250 000 Topographical maps were added to facilitate reference when zooming in.

After completion of the initial analysis the methodology was applied in the identification of a school which may be suitable for the establishment of a fog collection system. This was done as part of a community project run by a group of undergraduate Meteorology and Geography students. For logistical purposes, the new school site had to be within 25 km of the existing fog net at the Tshanova Primary school where the student group intended to do maintenance work to the fog collection system that was originally build as part of the WRC project in 1999 and is still providing water to the school and the local community. Suitable schools in the 25km area were identified and topographical profile graphs were created to scrutinize the topography for features that by obstruct the influx of fog bearing air flow.

Figure 2 illustrates some of the conditions as presented by the profiles. Figure 2(a) indicates that topography towards the East and South East are particularly favourable for the influx and uplift of fog bearing winds towards Tshanova Primary School. Figure2 (b) shows that conditions towards the East seem favourable for the influx and uplift of fog bearing winds towards Tshiavha Primary School. Although topography towards the South East is not ideal, there may still be enough uplift to facilitate fog formation. Figure 2(c) demonstrates that high peaks towards the East and South will prohibit the influx of fog bearing winds towards the Maname Primary School.

The success of the existing fog collector at Tshanova Primary School supported the results obtained from the GIS analysis. The positive results regarding the Tshiavha Primary were aided by studying Google Earth images to further analyse the possible movement of air along valleys in the region. With the consent of the headmaster of the Tshiavha Primary School, the Community Project students from the University of Pretoria continued with the planning, and eventually the construction of the fog collector in May 2007. On site observations in the same year at all three schools validated the results of the GIS process.

a) *Tshanova Primary School.* ***b)*** *Tshiavha Primary School* ***c)*** *Maname Primary School*



Limpopo Province

Y axis = Elevation (m); X axis = Horizontal distance (m)

Case study 2: Eastern Cape

In 2008 Prof J van Heerden (University of Pretoria) and other members of Cloud Water Concepts cc were requested by the Executive Mayor Mr. G.G. Mpumza of the Alfred Nzo District Municipality (ANDM) in the Eastern Cape to make recommendations on the suitability of several possible fog water collection sites in the municipal area. To facilitate the report on the suitability of these sites, a GIS analysis was employed.

In the Eastern Cape Province (ECP) fog as well as stratus and stratocumulus clouds form against the seaward side of mountain ranges (Olivier & Van Heerden, 2008). The area is significantly more complex to analyse compared to the Limpopo province as the mountain ranges and valleys are more dissimilar in orientation. In this case, eight possible sites were inspected, their geographical positions determined, and careful observations made of the terrain suitability, aspect and slope.

To complement the observed parameters of each site, a Geographic Information System (GIS) height and terrain analysis was performed. Although several other factors such as type of soil, accessibility, distance to nearby households and a suitable construction site were also included in a weighted final analysis, the GIS study was only concerned with the wider topographical analysis. The results of this GIS study then formed an integral part in the suitability classification of the sites. A coarse 1km DEM was used as it was the only raster dataset available at the time.

A reclassification of elevation zones and slope aspects revealed the suitable slopes. In order to determine whether terrain features located seawards of the site will interfere with the cloud movement, the elevation of the terrain was plotted in all four directions (NE, E, SE and S) up to a distance of 50 km from the site. Each plot showed whether higher ground may obstruct the influx of cloud bearing winds. The average terrain slope in each of the four directions was considered, with the emphasis on the 25 km closest to the site. A sharp slope immediately eastwards of the site position was considered favourable. A number of topographic profiles were drawn for each of the 8 proposed sites. This was applied to support the weighted classification which ultimately rated the sites as A (very good), B (good), C (requires further analysis) and D (not suitable). To explain the topographical analysis, some of the results for two of the eight sites are discussed below:

Possible site at Mt Hargraves (30º23˙46˙˙S;28 º49˙15˙˙E)

Considering orographic features as illustrated in Figure 3, the site is not obstructed by higher ground in the directions NE and SE. The curved fit line shows a general downward pattern for at least 25 km from the site. The visible sharp slope on the eastern side of the site is an added benefit. Mt Hargraves thus seems suitable in terms of orographic features and was classified as an class A site after the weighted analysis including the other parameters mentioned.

Possible site at Mgubo (South) (30 º26˙30˙˙S;28º42˙37˙˙E)

In the case of the Mgubo site, the profiles in Figure 3(b) show that cloud formation will be seriously hampered at this site and it was classified as an class C site after the full weighted analysis.

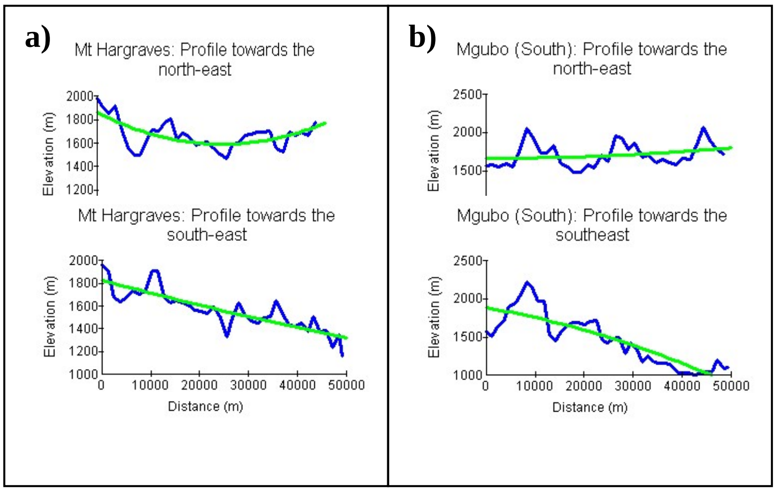
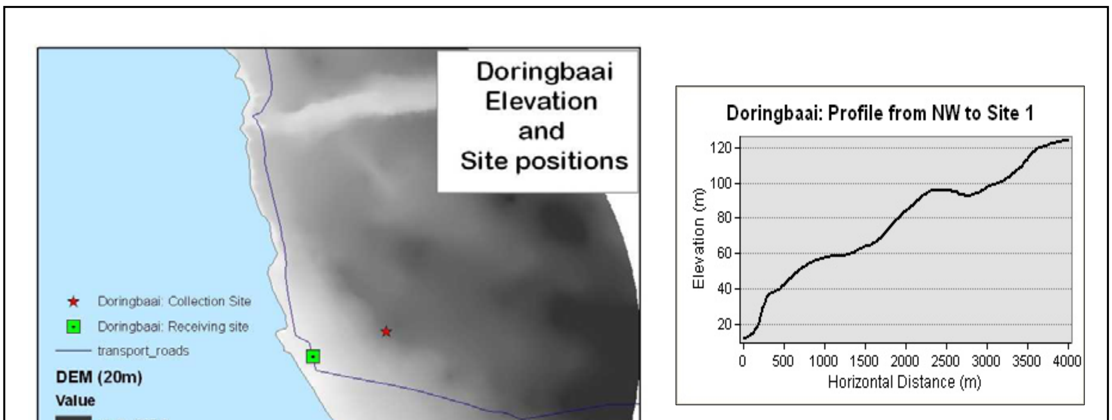


Figure 3: Orographic features at the Mt Hargraves and Mgubo(South) sites. Elevation and the smoothed elevation (curved fit)

Case study 3: Western coast

Conditions along the west coast are considerably different to those in other fog prone regions. Elevation zones are much lower than in the east and influx of moist air is from the west, north west and south west. The fog prone areas here are located in a narrow sliver running parallel to the western coastline. The communities in need of water are situated at the coast but the fog density and frequency are higher towards the inland in elevated areas. The extent of the study area are significantly smaller and the differences in elevation relatively small. Therefore a much finer raster resolution, a 20m DEM derived from 20m contours, was applied.

Although the criteria changed, the methods used in the GIS analysis were similar. Areas close to the three towns where land use would permit the construction of fog collectors were identified and these areas were then analyzed with the help of the GIS software surface analysis tools. The position of a possible fog collecting site and a proposed receiving site, as well as a topographical profile employed in the analysis procedure with regards to the town of Doringbaai where conditions look promising, are illustrated in Figure 4. Discussions with local municipalities are still in progress.



Site 1

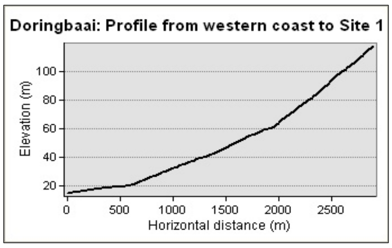


Figure 4: Doringbaai: Position of sites and topography

Conclusion

Although a GIS analysis will help to reduce the amount of fieldwork necessary for identifying potential beneficiaries of fog collection projects, the deployment of such systems will entail much more than just identifying potential slope areas. This research should be seen as part of the overall screening process which will aid decision makers in identifying those communities where the deployment of fog-net water collection systems will yield long term sustainable benefits. The findings of this preliminary study warrants further analysis and refinement of the procedures and methodology involved in creating a GIS based tool for aiding in the planning and implementation of sustainable fog water collection systems.

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