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Susanna Jacoba Henrico

University of Pretoria

Serena Coetzee

University of Pretoria

Antony Cooper

Built Environment Unit, CSIR, Pretoria, South Africa

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Analysing the practical feasibility of FOSSGIS in military operations – A Cholera outbreak use case

Susanna Jacoba Henrico^{*a}, Serena Coetsee^a, Antony Kyle Cooper^b

^aUniversity of Pretoria, ^b Built Environment Unit, CSIR, Pretoria, South Africa

KEYWORDS: Open source software, military operation, geographic information system, QGIS, hot spot analysis, kernel density estimation, buffering, viewshed analysis

ABSTRACT:

Remaining ahead of the enemy in all circumstances is crucial to any military power. Geographic information systems (GIS) can provide the military commander with geospatial information about the theatre of war to assist with the planning and execution of a mission. Unfortunately, technology usually comes at a price. GIS is no exception. The cost of acquiring and maintaining GIS software licenses, as well as training staff in the use of the software, needs to be considered. The question arises whether open source software, which can be used without any software license expenses, is a feasible alternative in military operations. The problem is that the perception exists that open source GIS software is neither user-friendly nor mature enough to be used in military operations. This study evaluates the functionality of an open source desktop GIS product in a military operation use case. A list of specific GIS functionalities was compiled based on the literature study and by developing a use case. The functionalities were executed in QGIS. Results were compared against results of the same functionalities in ArcGIS, which is widely used in military operations. Results show that all GIS functions tested by this study could be performed by both software products. These results are interesting because it means that FOSSGIS can be successfully deployed by units or directorates that has limited funds available to expand the existing GIS capabilities for military operations.

1 Introduction

In military operations, considerations for military equipment, infrastructure and activities (“What?”, “When?”, “Where?”) are important. They develop a perception (“How?”, “Why?”) of the enemies’ type and number of equipment available, force readiness, present activities involved in and future planned activities. These considerations and perceptions are enhanced by focusing and paying attention to terrain as one of the important factors to consider during planning. The terrain determines the type of military vehicles and weapon systems that can be deployed and used. Terrain layout also influences the execution time of certain maneuvers or operations (Lodi et al., 2014). Even communications are influenced by the terrain. It is therefore imperative to determine line-of-sight as this factor is crucial for certain kinds of communications, as well as for some weapon systems (Datz, 2008). Furthermore, geomagnetic information affects equipment that could be used in an operation. This is where GIS plays an important role in support of military operations. It provides a means to the military commander in the form of geospatial information about the theatre of war (Ünal and Mustafa, 2002). GIS analyze information about the terrain (i.e. land cover) and population (i.e. land use) and consider other sources such as remotely sensed imagery to produce geospatial products (e.g. maps). These products are critical aids to the commander in developing a comprehensive picture of the terrain layout and land use, as important factors to assess before making any decision.

The cost of acquiring and maintaining GIS software licenses, as well as training staff in the use of the software, can become a significant portion of the costs of a military operation. As a result, the number of licenses that are purchased are sometimes limited, reducing the potential benefits of GIS to the military planner. Donnelly (2010) cites that there has been an increase in recent times in the development and implementation of FOSSGIS for the international geospatial community. Deek and McHugh (2007, p.1) states that the open source movement is “a worldwide attempt to promote an open style of software development more aligned with the acceptable intellectual style of science rather than the proprietary modes of invention that have been characteristic of

* Corresponding author

modern business". The open source movement supports the use of open source licensing, which means that software can be freely used, modified, and shared.

While open source GIS products exist, in military communities, the perception exists that open source GIS software is neither user-friendly nor mature enough to be used in military operations. This perception is based on personal experience, e.g. based on discussions with colleagues and experience in a defence force work environment where the use of QGIS was proposed, but colleagues were hesitant to embrace the idea.

This paper presents first results of a study to explore open source GIS software as a feasible alternative in military operations. A use case of a military operation was developed. GIS functionalities required for this use case were identified and then tested using QGIS (www.qgis.org), an open source desktop GIS product. Test results were compared against results of the same functionalities in ArcGIS (the baseline) and qualitatively analysed and explained. A number of case studies were done to compare ArcGIS to QGIS (GIS Geography, 2016, Dempsey, 04 November 2012, Duggan, 02 February 2015). However, the study reported in this paper is unique because it incorporates military operational requirements related to a specific use case. Secondly, it is not a competition to find a "victor", but rather an objective study to determine whether FOSSGIS can be used in a specific military operation considering certain operational GIS functionalities (specified by the use case).

The remainder of the paper is structured as follows. Section 2 describes the use case, a Cholera outbreak for which a military operation is planned. Section 3 explains how the GIS functionalities were identified and how tests were conducted. In section 4, each test is described, the QGIS and ArcGIS results are presented and subsequently analysed. The section is concluded with a table that summarizes the test results. Section 5 presents conclusions and describes further work to be done.

2 Use case: Cholera outbreak

Cholera is a highly infectious disease that still affects many parts of Africa, as well as other parts of the world, such as south Asia and Latin America. The disease is caused by drinking or eating contaminated water or food. It is often found in areas with "poor sanitation, crowding, war, and famine". If left untreated, it can lead to death (WebMD, 2016). Cholera outbreak was selected as the scenario for this use case, since it is a very real humanitarian disaster in which the military can be tasked to render support in containing the spread of the disease and providing aid to infected persons. This is an example where the military is tasked to conduct a military operations other than war (MOOTW).

After consultation with commanders involved at different levels and in different roles in operations, (personal communications: Davids, J.M., 12 May 2015; Van Niekerk, A.F.V., 04 September 2015; Venter, J.D., 26 May 2015 and Wylie, A.C., 05 October 2015) a use case was developed (Adolph et al., 2002, Bittner, 2002) that describes the geospatial tasks and products to be executed and produced in a typical military operational scenario for the South African National Defence Force (SANDF). This fictitious scenario describes a health risk disaster in the form of a Cholera (Zuckerman et al., 2007) outbreak in the Pilanesberg area located in North West province in South Africa, 160 km west of Pretoria (see Figure 1). The Pilanesberg area is a Game Reserve with numerous rural villages surrounding this area. However, Pilanesberg is a mountain, circular in shape which was formed by an ancient volcano eruption some 1 200 million years ago.



Figure 1: Study area – Pilansberg, South Africa

The SANDF was tasked by the Minister of Health to assist in controlling this outbreak, because the SANDF is the only national entity with a medical deployment unit capability. The scenario is fictitious (see Table 1), but it draws on potential military operations in response to disaster relief.

Table 1: Use case description: Cholera outbreak for which a military operation is planned

The SANDF is requested by the Ministry of Health to assist in curbing the outbreak of Cholera in the rural population of the Pilanesberg area, North-West province, South Africa. The Chief of the SANDF tasked the Chief Joint Operations (CJ Ops) to establish an operation room within the disaster management centre and to deploy the following forces to manage and control this health disaster:

- 1. The South African Military Health Service (SAMHS) were tasked to set up a Medical Post.*
- 2. Two Infantry Companies (Inf Coy's) responsible for barricading and securing the contaminated area.*
- 3. One SA Army Engineer Squadron (SAAEF Sqn) consisting of a water purification unit. The SAAEF Sqn will be responsible for purifying the contaminated water.*

In order for the SANDF to assist, the following geospatial tasks are required from the GIS commander, whom has to report his operational plan to the operational commander:

- i. The individual households that were reported as households with Cholera have to be digitised using the Spot 6 image as backdrop in order to zoom into the residential areas. The commander then wants an area of 10 km² to be demarcated around a convex hull of all the households, since this will be the "area of operations".*
- ii. The high risk Cholera areas within the Pilanesberg must be indicated. The key hot spot area should be*

- determined. It is required to produce a GIS hot spot analysis layer indicating these areas.*
- iii. The commander of the operation must know the terrain in his area of operations to be able to make proper operational decisions, such as entry and exit routes as a time saving factor and locations of open terrain for demarcating helicopter landing zones. It is therefore required that a map showing "hillshading" be made in order to show the mountainous areas in relation to the rest of the area.*
 - iv. One of the factors that influence the spread of Cholera is a very heavy rainy season, which was the case in this region. It is required to produce a flood simulation layer in order to anticipate the potential influence on the spread of the Cholera, should the water level rise if there is more rain.*
 - v. An important aspect during any military operation is communications. The GIS commander will be tasked to map those areas within the area of operations that are visible from the identified HQ position in order to determine line of sight visibility for radio communications.*
 - vi. A layer indicating locations of helicopter landing zones (HLZ) must also be created. Firstly, existing helipads will be identified; secondly, additional suitable HLZ's must be added to the layer.*
 - vii. An area where a medical treatment centre can be placed should be established for the Medical Task Team's operations. It is required to produce a layer indicating the most suitable location to deploy this medical post and to show other existing hospitals in the area of operations.*
 - viii. The commander needs to know the locations of the closest police stations.*
 - ix. The infantry commander needs to show his members where to place their roadblocks.*
 - x. A safe water supply for the rural population of the Pilaesberg area has to be ensured. It is required to produce a layer indicating the most suitable place to deploy the SAAEF water purification plants.*

3 Method

An initial literature study provided insight into the precise role of geospatial information in the military (MacEachren et al., 2005, Jacobs, 2005, Palka et al., 2000, Swann, 1999, Tuner, 2003), the levels of war and the use of GIS on each of these levels. Based on the literature study, it was decided that a first study should focus solely on the operational level of war. Additional studies will focus on the use of GIS for the military in other levels of war. A study was then made on the use of GIS on the operational level of war, after which a list of typical GIS outputs were identified that are often required by the operational commander. The study was conducted in three stages, namely:

- i. Stage 1 – Identifying GIS functionalities: The GIS functionalities that are needed to produce the GIS outputs were identified based on the literature study, as well as the use case.*
- ii. Stage 2 – Means and methods to assess GIS functionalities: The means and methods (henceforth known as tests) necessary to assess the functions identified in Stage 1 were determined and developed. These functions produces specific GIS output products and the tests necessary to produce these products were performed by both ArcGIS and QGIS software for comparative purposes.*
- iii. Stage 3 – Conducting GIS functionalities: This stage consisted of conducting the tests developed during Stage 2. These tests served the purpose to qualitatively evaluate the maturity of QGIS by comparing it to ArcGIS as the baseline or reference. The tests were conducted independently in QGIS (version 2.8.5 Wien) and ArcGIS (version 10.2).*

A number of reasons exist for choosing QGIS as the software package to be compared with ArcGIS, mentioned below. However, the main contributing feature is that QGIS is already partially incorporated within the SANDF geospatial domain. A two-week course has already been developed by the SANDF and is presented at entry level to unit personnel. Other reasons are:

- i. When examining the graphical user interface (GUI) it looks similar to the GUI of ArcGIS.*
- ii. It is easily available and downloadable over the internet and easily installed.*
- iii. Its operating costs are very low.*
- iv. Support for this software is available in a number of ways.*
 - 1. Firstly, online through the international QGIS user community,*
 - 2. Secondly, the support in terms of training for the software in the RSA is quite extensive. There are a number of GIS institutions and other educational institutions offering courses on this software.*

3. Thirdly, there are also support documents available on the QGIS website as well as “Help tips” that appear when using the software.
- v. It can run on a variety of computer operating systems.
- vi. A number of easily assessable “plugins” are available that provides extra functionalities to QGIS.

In this paper, the results of four tests are presented, namely the buffering an area of operations, the Cholera hot spot analysis, the creation of a visibility layer and the creation of a layer of locations for water purification plants. These tests correspond to geospatial tasks, described in i., ii., v., and x. in the use case (see Table 1). The tests were chosen because they can easily be related to and applied in other operational scenarios and they are therefore pertinent GIS functionalities needed by military operations.

4 Results

This section presents the results of the four tests that were chosen for discussion in this paper. For each test, there is a description of the test, the ArcGIS baseline results and discussion, followed by the QGIS test results and discussion, and finally, a comparative analysis of the test results.

4.1 Test 1: Buffering an area of operations

Buffering is a very common and often used analysis tool by GIS commanders since it involves proximity analysis around points, lines or areas. The commander wanted an area of 10 km surrounding the reported Cholera cases to be demarcated as the “area of operations”. Before building this buffer, the individual Cholera cases were digitised in a point shapefile. The Spot 6 image was utilised as a background for the residential areas in order to identify and capture households identified with Cholera.

4.1.1 ArcGIS baseline results

Buffering is one of the standard geoprocessing tools in ArcGIS (see Figure 2). The process is relatively simple as long as the user specifies the correct unit of measurement. The fact that one can choose the unit of measurement via a dropdown list in ArcGIS is one of its benefits. In ArcGIS, even the inexperienced GIS user can build a buffer since ArcGIS will correctly build the buffer even if the data used is not in a projected coordinate system (Chang, 2006).

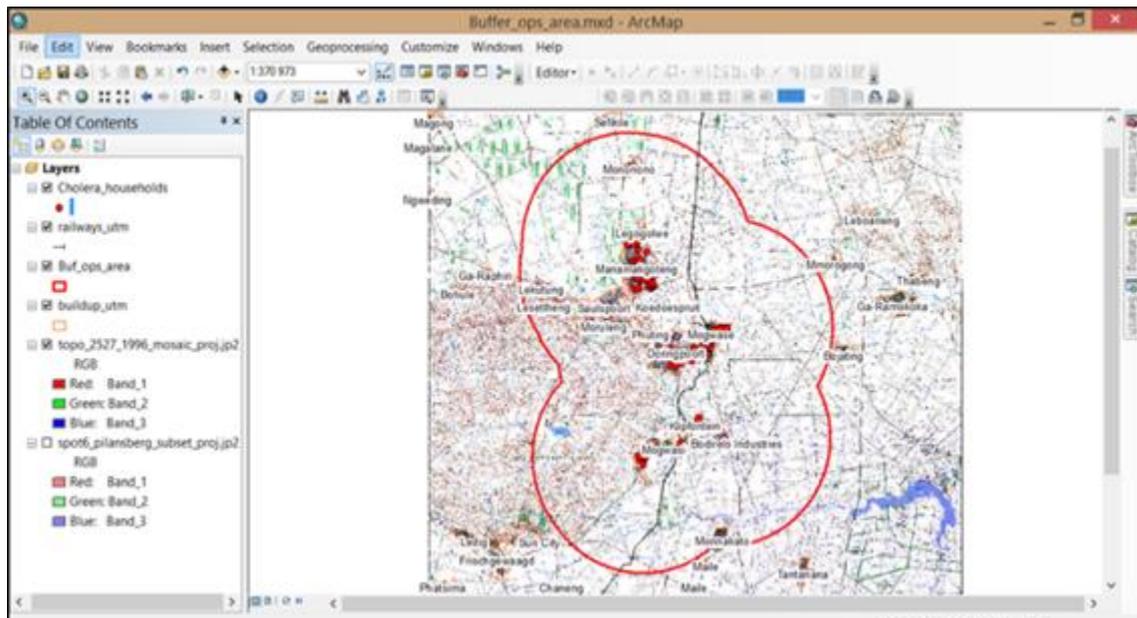


Figure 2: Buffering analysis result obtained – ArcGIS

4.1.2 QGIS results

Buffering is also one of the standard geoprocessing tools in QGIS (see Figure 3). Although the process itself is very similar to that in ArcGIS, the GIS user has to know that the buffer process will not work correctly in QGIS if the data to be buffered is not in a projected coordinate system. The user will also not be able to specify the unit of measurement and will therefore be required to have a basic knowledge of coordinate systems and their respective units of measurements. In this test, the study data was defined to WGS84/UTM grid zone 35S. As UTM was used, all measurements are in meters.

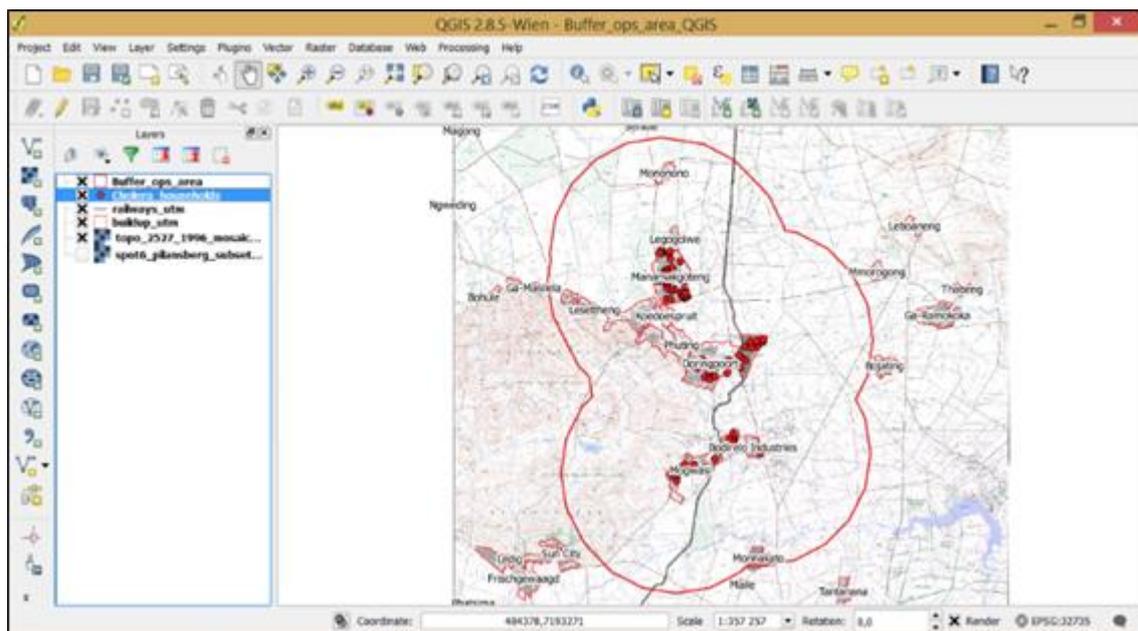


Figure 3: Buffering analysis result obtained – QGIS

4.1.3 Comparative analysis of results

The results obtained with both products were satisfactory. Both software products obtained a buffer of a very similar size and the operational request would have been satisfied by both. A single difference was observed. In order for the GIS operator to successfully complete the buffering process in QGIS, he/she will need to have a

basic understanding of coordinate reference systems (see paragraph 4.2.2). This will assist GIS operators to comprehend why the buffer will only be correct if the data is projected.

4.2 Test 2: Cholera hotspot analysis

One of the tasks of the SAMHS is the categorisation of patients based on a set of evaluations in order to determine priorities for emergency evacuation and treatment. The status of the categorisations may change continuously as the condition of casualties can improve, worsen or spread to other areas. The SAMHS commander must constantly be informed of which areas in the operational area take priority at that point in time. A hotspot analysis (Lin et al., 2010) can serve as an extremely valuable tool to assist the commander with operational planning when areas for the deployment of SAMHS treatment centres have to be determined. The GIS commander must be able to show the operational commander the high-risk Cholera areas within the area of operations. A “hotspot” analysis is therefore vital. This analysis will allow the commander to see which areas have a higher than average incidence of Cholera.

According to Chainey et al. (2008) “hotspot mapping is a popular analytical technique...”. There are a number of different techniques that are used for the identification of hotspots, amongst others, kernel density estimation, point mapping and grid thematic mapping. Kernel density estimation was used for this particular Cholera hotspot project. Kernel density estimation computes the density of features in a neighbourhood of cells around those features. In this test, the density was calculated for point features but it can also be used for line features. The surface value is highest at the location of the point (the reported Cholera households) and it reaches zero at the search radius distance from the point. The radius was specified at 1500 m for this test.

4.2.1 ArcGIS baseline results

The kernel density tool was utilised in ArcGIS in order to perform the hotspot analysis (see Figure 4). Kernel density is one of the tools available within the Spatial Analyst extension of ArcGIS. In order to get the best results with the particular tool in ArcGIS, the environment settings must be set before performing the analysis. This is to ensure that the entire hotspot analysis result is displayed within the viewing window and not cut off to exclude certain areas. The processing extent was set to “same as display”. In order to further enhance the visual effect of the analysis results, the first class colour was set to “no colour” (i.e. transparent). If the first value/class is not set to “no colour”, the background data that must provide a frame of reference to the military commander is not visible.

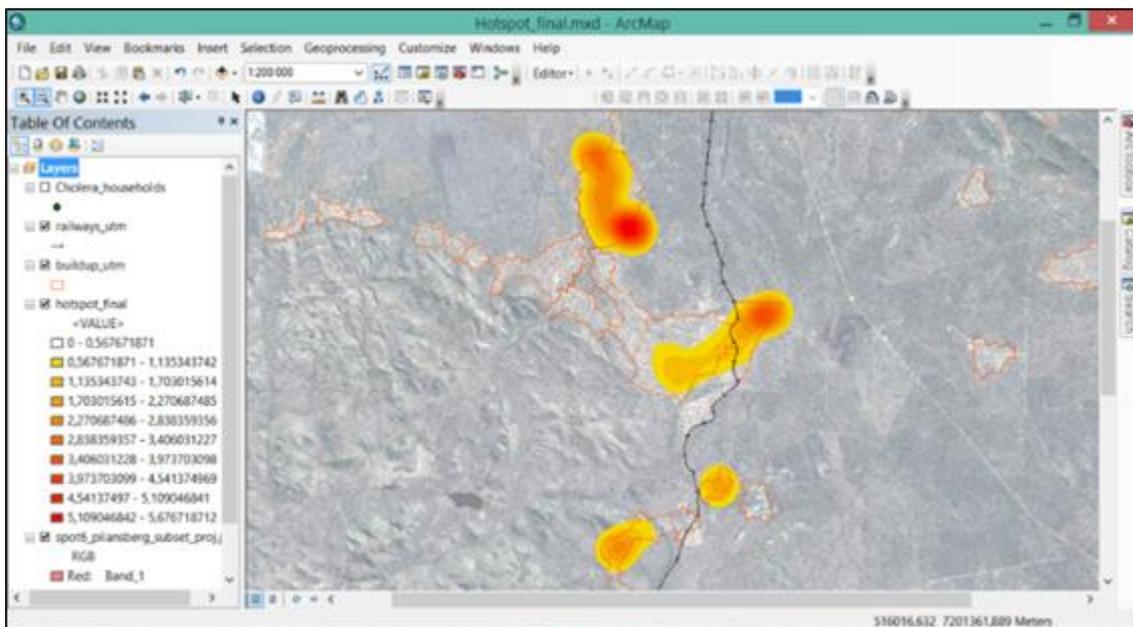


Figure 4: Hotspot analysis result obtained – ArcGIS

4.2.2 QGIS results

The “Heatmap” plugin was downloaded in order to perform the hotspot analysis in QGIS (see Figure 5). This plugin also uses kernel density estimation in order to create a density raster (“heatmap”) of an input point layer.

In QGIS the initial output product will appear as a black and white (single band grey scale) raster image. The properties of this raster layer must then be changed to a single band pseudocolour and classified using the equal intervals methods according to the number of classes that the user requires. The number of classes used was ten and the first class's colour was also set to "no colour" (i.e. transparent), which was the same as in the ArcGIS test.

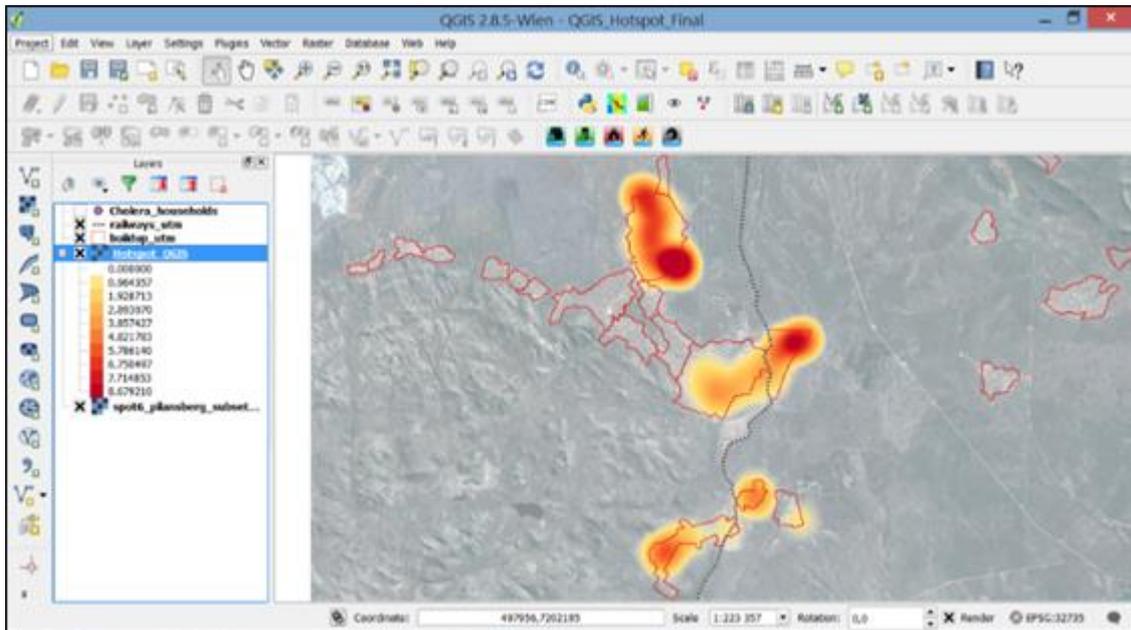


Figure 5: Hotspot analysis result obtained – QGIS

4.2.3 Comparative analysis of results

The Cholera hotspot analysis can be completed successfully in both ArcGIS and QGIS. Although there is a minor difference (see Figures 4 and 5) in the manner in which hotspot results are displayed in the two software products. Both results would be acceptable to the operational commander. It is however interesting to note why the difference in these results exists even though in both products a kernel density analysis were done. In QGIS more detail is visible in the end-result. In ArcGIS, the KDE is based on the default quadratic kernel function and in QGIS the Quartic (biweight) function/shape was chosen. In an email on 03 March 2016, J.S. Evans (Affiliate Assistant Professor at University of Wyoming, Laramie, WY) stated that the visible difference has to do with the degree of polynomial in the respective kernel density functions: a quartic kernel is a fourth order polynomial, whereas a quadratic kernel can, theoretically, take any form but generally represents a lower order (second) polynomial. As in trend functions, lower order polynomials will not pick up as much localized detail, given the same bandwidth parameters.

Results in both products will give the commander the ability to see areas of higher density of Cholera. The tests were conducted with different radii, as well as with different display colour settings, in order to get the best results in both systems. It is advisable for GIS operators to have background knowledge concerning raster images when doing any type of raster analysis, since this type of analysis is commonly more advanced than vector analysis functions. This applies to both products.

4.3 Test 3: Creating a visibility layer

The visibility or viewshed analysis is a vital and dynamic tool for the military. In this use case, it was used to see whether radio communications would be possible in all areas from the main HQ position. The Madutle Primary School was chosen as the ideal HQ position since it is in the centre of the Cholera outbreak, has all the necessary infrastructure needed for the operations and has a sport field that can serve as a helicopter landing zone. The location of this school (HQ), where the radios for communication would be set up, was made into a separate point layer that was used as the "observer point" for the visibility analysis.

Radio communications work on the principle of "line-of-sight", therefore, areas with no visibility from the HQ will have poor or no radio signal. In areas that the radio signal will not reach, deployment of relay stations should be considered. In other military situations, visibility or viewshed analysis is used for to determine

artillery observer positions etc. and the extent to which the artillery observers will be able to see and gather intelligence (visible terrain for targets and plotting of enemy positions). The radio antenna-height was specified at 10 m; if the antenna height is too high, it gets unstable and unpractical.

4.3.1 ArcGIS baseline results

In ArcGIS, the visibility tool in the 3D Analyst extension was used to execute this test. Certain attributes must be added to the Madutle Primary School (observer point) layer before attempting to do the visibility analysis. This step was included in the analysis because in a military scenario, the commander would like to be able to specify the height of the observer point (in this case the height of the antenna for VHF radios), as well as the radius distance from the observer point. If however, a person would only be interested in a visibility analysis from the current height of the observer point and would like to include the whole study area in the analysis the “Viewshed” tool in ArcGIS is sufficient.

The Interactive Visibility tool Add In was downloaded, which helped a lot with adding the observer, input specifications in a more automated and faster way than manually adding individual attributes to the attribute table. The radius from the HQ was specified as 20 000 m and the height of the antenna (observer) was specified as 10 m. The remaining default values were accepted. ArcGIS automatically displays visible areas as a “Visible” layer and areas that are not visible as a “Not Visible” layer. The default colours were changed to red (visible) and green (visible). The results are illustrated in Figure 6.

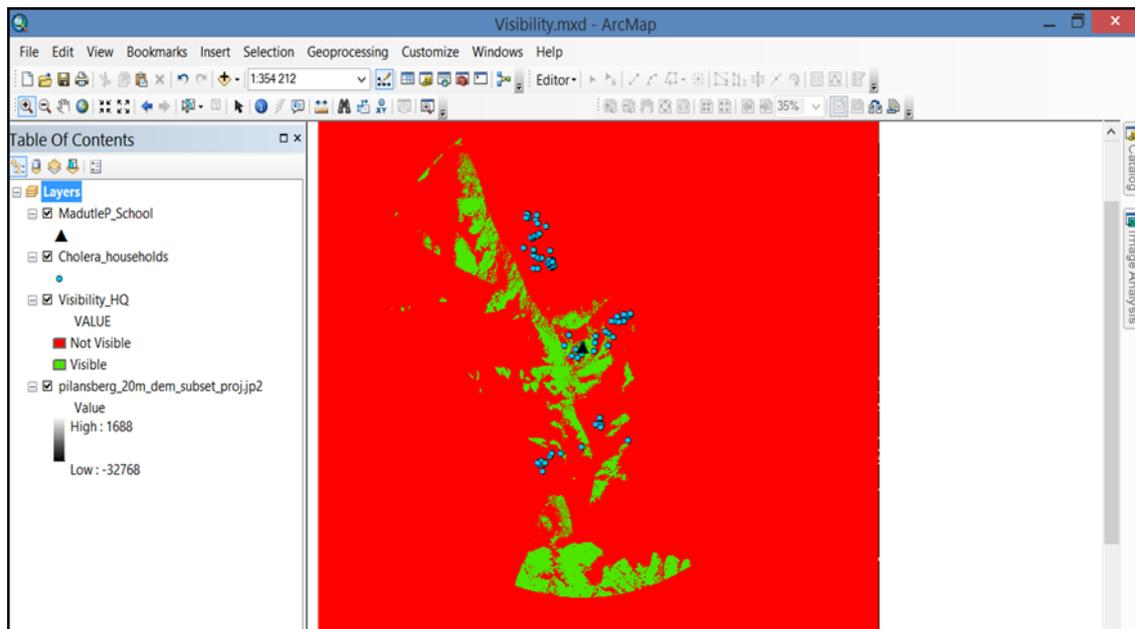


Figure 6: Visibility layer result obtained – ArcGIS

4.3.2 QGIS results

The Viewshed analysis plugin was downloaded for this analysis in QGIS. In the viewshed analysis tool, the user can specify all the observer parameters and choose the type of output (i.e. binary viewshed, intervisibility, intervisibility depth and horizon). The specified observer parameters were the same as with the ArcGIS test, therefore the search radius was set to 20 000 m and the observer (antenna) height to 10 m. A binary viewshed was done, which provides a simple yes/no value for each pixel. Figure 7 [a] indicates the result of the viewshed analysis before adjustments were made to the raster layer properties. In Figure 7 [b], the final result can be seen.

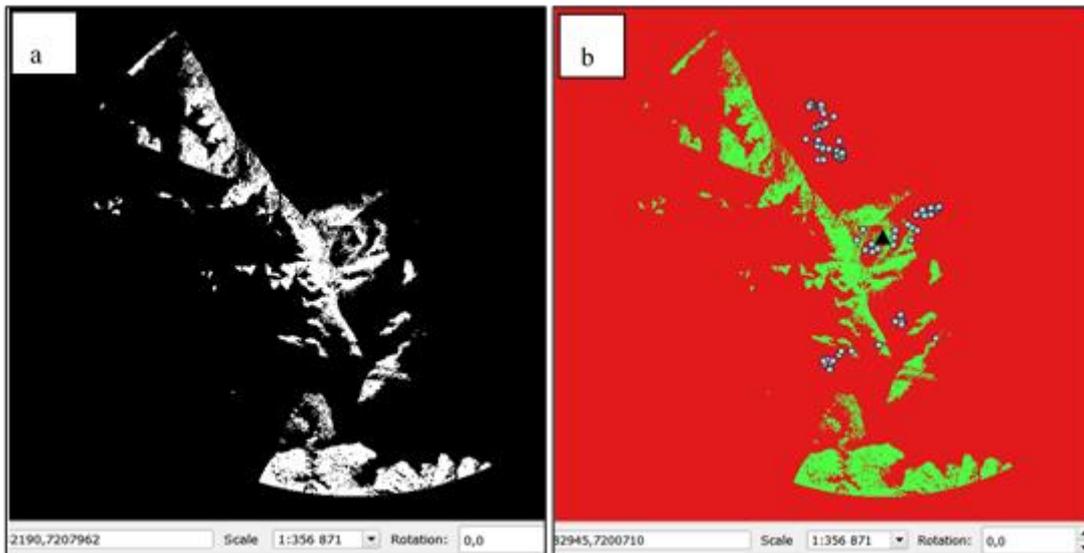


Figure 7: Visibility layer result obtained – QGIS

In Figure 8, an example was made to show another possibility for presenting the results to the commander. In this example, the green areas represent visible areas (areas where radio signals will be good) with the topographical map as base layer for orientation. Areas with no visibility are transparent.

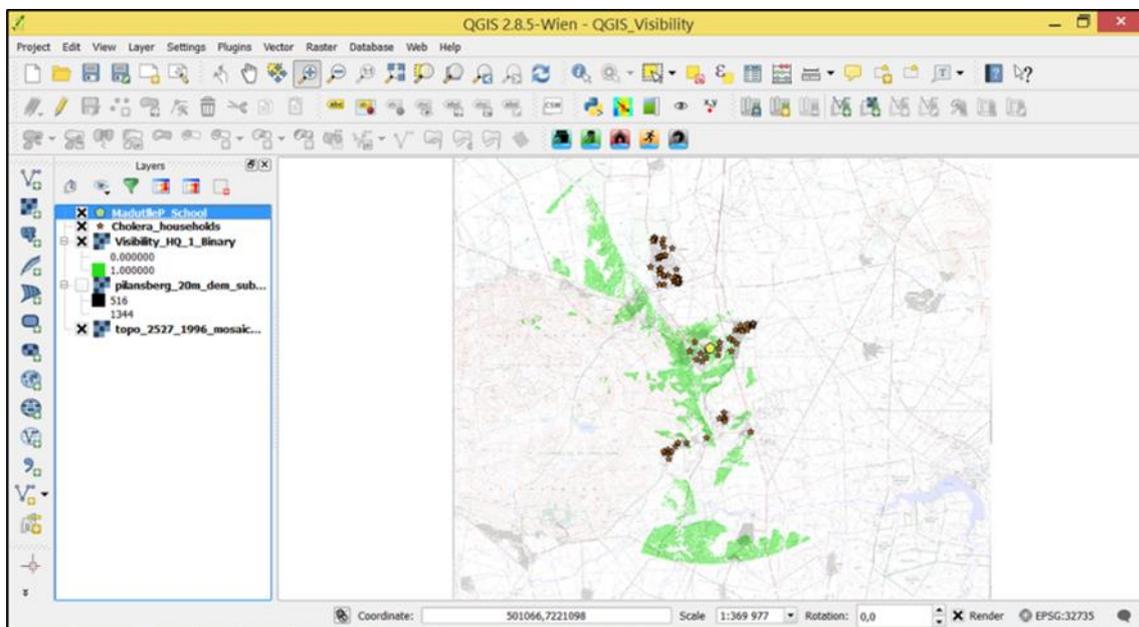


Figure 8: Visibility layer combined with the topographical map

4.3.3 Comparative analysis of results

In ArcGIS, the process of initially entering the input values for the observer point is a bit more involved than in QGIS because in ArcGIS 10.2 the values must be added as attribute values in the observer point layer. The downloaded “Interactive Visibility Add In” helped to simplify this process since it guided the user towards entering the desired values for the observer point’s attributes. In QGIS, these attributes were automatically available in the “Viewshed analysis” plugin. However, according to the latest documentation, ArcGIS 10.3 has resolved this.

In ArcGIS 10.3, a new tool is available (Viewshed 2 tool) that is similar to the dialog box available in QGIS, where input parameters for observers can just be filled in without adding additional fields to an attribute table. The styling in QGIS is slightly more complex than in ArcGIS, due to the fact that the initial results are displayed as a single-band grey that needs to be changed to a single-band pseudocolour and then classified into two colour classes. This process is certainly not difficult, but the user should preferably understand rasters to some extent in

order to manipulate the raster properties and ensure a visually correct product. The result in QGIS displays as a single band greyscale, which must then be changed to a single band pseudocolour and classified into two colours according to equal intervals method and the displaying colours, have to be set to the desired ones. The legend in QGIS must also be renamed to indicate “Visible” and “Not-visible” which is easy to do, but this was done automatically in ArcGIS.

4.4 Test 4: Creating a layer of water purification plants

The SA Army Engineer Formation (SAAEF) must deploy water purification plants in the Cholera affected areas. The SAAEF commander wants advice on the ideal location for placement of these water purification plants. The plants must be placed on a flat surface, close to a river. The GIS operator will therefore firstly do a slope analysis. The slope of the area close to a river must be less than 5 degrees. Thereafter, locations for individual water purification plants must be digitised.

4.4.1 ArcGIS baseline results

The ArcGIS Slope analysis tool gives the user an option to choose between doing a degree or a percentage slope analysis. The styling of the point symbols was made easy by the wide variety of symbols available from the existing symbol sets in the symbol selector dialog box. The results of the analysis are illustrated by Figure 9.

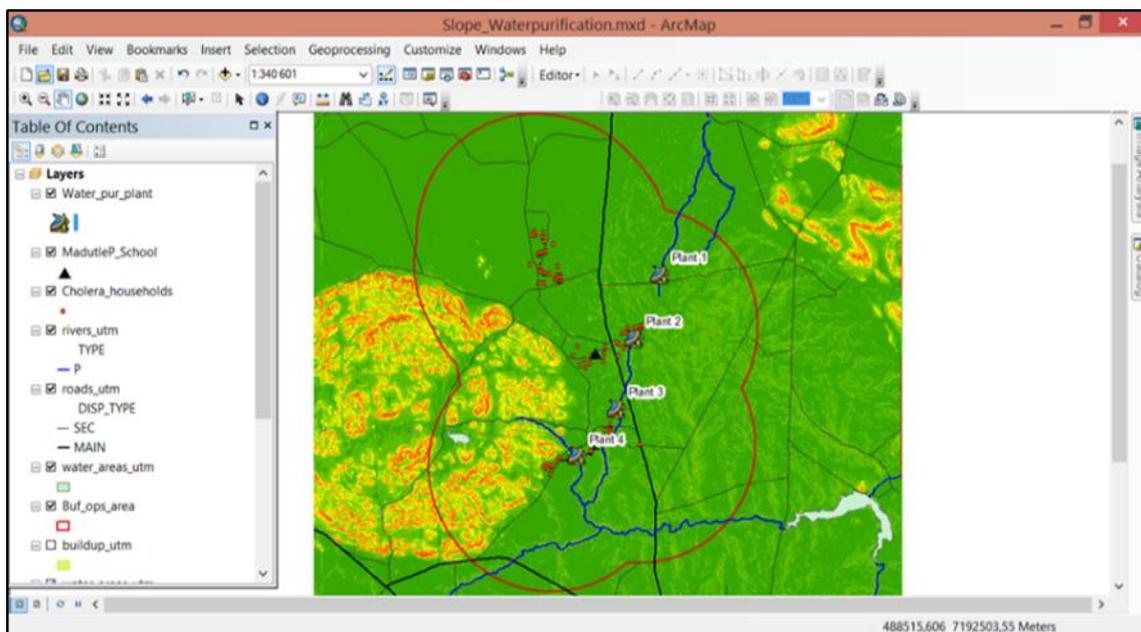


Figure 9: Water purification plants result obtained – ArcGIS

4.4.2 QGIS results

In QGIS the type of slope analysis (degree or percentage) cannot be chosen. The number of point symbols for point features within the existing QGIS style library was limited. Additional point symbols in .SVG format were downloaded from the internet and copied to the SVG folder located in the relevant QGIS program files directory (C:\Program Files\QGIS Wien\apps\qgis-ltr\svg). This extended the range of point symbols in QGIS extensively. QGIS symbols are available from a wide variety of internet sites at no cost. Figure 10 provides an illustration of the results of this analysis.

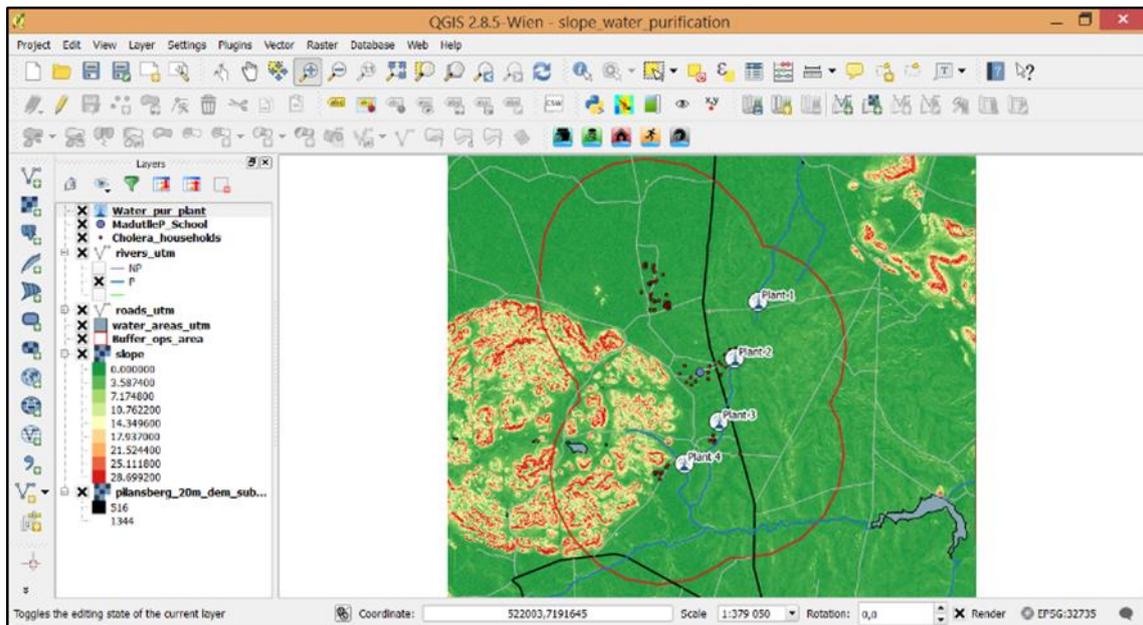


Figure 10: Water purification plants result obtained – QGIS

4.4.3 Comparative analysis of results

In a military operation where internet services might not be available, this part of the process will have to be done when deployment preparation is performed. On the plus side for flexibility and extensibility, in QGIS new symbols can easily be created by a user by combining more than one symbol. The slope analysis (needed to determine the ideal location of water purification plants) in both ArcGIS and QGIS, was effective for determining the degree slope, which was the required output in this use case. However, in the ArcGIS Slope analysis tool, there is also an option to perform a “percentage slope” analysis.

4.5 Summary of test results

Table 2 provides a summary of the test results described in the previous sections.

Table 4: Summary of test results achieved

TEST NAME	SUMMARY
Test 1: Buffering an area of operations (4.2)	<ul style="list-style-type: none"> The results obtained are similar. In order for the GIS operator to successfully complete the buffering process in QGIS, he/she will need to have a basic understanding of coordinate reference systems. The unit of measurement in QGIS cannot be chosen in the buffer analysis dialog.
Test 2: Cholera hotspot analysis (4.1)	<ul style="list-style-type: none"> The hotspot analysis was successfully completed in both software products. A difference in the results obtained was observed. In QGIS, more detail is visible and the resulting polygons appear to be slightly smoother. The buffer area sizes created in QGIS are approximately 104 km², whereas in ArcGIS the buffer sizes are 44 km². Therefore a significant difference of approximately 60 km² of extra buffer areas are displayed created QGIS. In ArcGIS, the kernel density estimation is based on the quadratic kernel function (by default) and in QGIS the Quartic (biweight) kernel function/shape was selected.
Test 3: Creating a visibility layer (4.3)	<ul style="list-style-type: none"> The desired end-result could be achieved in both products. In ArcGIS, the process of initially entering the input values for the observer point is a bit more complex in QGIS than in ArcGIS 10.2. In QGIS, the required attributes were automatically available in the

	<p>“Viewshed analysis” plugin. ArcGIS 10.3 has resolved this in the new “Viewshed 2” tool.</p> <ul style="list-style-type: none"> • The inexperienced user might consider the styling in QGIS to be more complex than in ArcGIS. The result in QGIS displays as a single band greyscale, which must then be changed to a single band pseudocolour and classified. • The legend in QGIS was renamed to indicate “Visible” and “Not-visible”, which was done by default in ArcGIS, but can also be edited if needed.
<p>Test 4: Creating a water purification plants layer (4.4)</p>	<ul style="list-style-type: none"> • In ArcGIS, the styling of the point symbols was made easy by the wide variety of existing symbols available. • In QGIS, the number of point symbols for point features was limited. Additional point symbols were downloaded from the internet in .SVG format. • In a military operation where internet services might not be available, this part of the process will have to be done as part of deployment preparation. • On the plus side of symbology with QGIS, new symbols can be created by the user by combining more than one symbol. • The slope analysis (needed to determine the ideal location of water purification plants) in both ArcGIS and QGIS was effective in applying a degree slope. • In the ArcGIS Slope analysis tool, there is an additional option to perform a “percentage slope” analysis.

5 Conclusion

From an empirical study and using a use case, certain operational level GIS functionalities were identified. These GIS functionalities were tested on both proprietary GIS software (ArcGIS) and using FOSSGIS (QGIS) and the outcomes were qualitatively compared. The following conclusions were derived from the study:

- i. Firstly, all the operational GIS functions described in the use case could successfully be performed using both ArcGIS and QGIS.
- ii. It is acknowledged that some of these GIS functions were on an advanced level and that in both software products training will therefore be needed.
- iii. Although all GIS functionalities could be performed using both software products, in most cases where the analysis result was in a raster format, the properties of the end-result in QGIS needed further “refining” since the raster output is first displayed as a singleband greyscale image. Although this is not significantly difficult to perform, the GIS operator will have to take cognisance of this aspect.
- iv. The default existing library of symbology within ArcGIS (especially with regards to point symbols) is more comprehensive than in QGIS. However, it is also possible to expand symbology in QGIS in two ways. For this further training and subject matter experience is required:
 1. Firstly, by downloading additional symbols in SVG format.
 2. Secondly, by designing symbols.

The fact that the native symbology functionality in ArcGIS exceeds that of QGIS, makes ArcGIS the software of choice when it comes to extensive military cartographic products. Units or directorates that produce maps and cartographic products on a large scale should therefore use ArcGIS as their primary cartographic tool.

With regards to the GIS functionalities tested, it can be concluded that FOSSGIS can be successfully deployed to units or directorates, especially to those with limited funds, to expand the existing GIS capabilities for military operations. This process will however require guidance and training. Without proper training and guidance any GIS can become a “dangerous tool”.

GIS is an important planning tool in the military and one that should not be denied to any military unit or directorate. FOSSGIS gives all units or directorates access to GIS. The advantages and benefits of exploring with a GIS without limits cannot go without mention.

FOSSGIS gives the user access to even advanced GIS functionalities without additional licensing costs. The user therefore does not have to pay extra to get access to the next level of functionalities, such as advanced spatial and terrain analysis functions.

Nevertheless, it needs to be acknowledged that when certain fees are paid to a proprietary software vendor, one can expect to receive a certain level of service or support from that vendor. This means that if the user encounters a problem with the software (for example a bug in its development), it can be reported and whilst it might not always be fixed immediately, the user can at the very least expect an answer. This can be crucial when troubleshooting in a mission-critical military operation. The FOSS community is aware of this need, and one of the solutions is the (paid) technical support offered by a variety of companies on the QGIS website.

FOSSGIS, and more specifically QGIS, opens a world of possibilities to the military. It means that institutions that would normally be deprived of this great planning tool because of costs can now have access to it. These units have access to the analytical power of an advanced GIS tool with all the functionalities needed to answer the commander's questions. Although the level of employment of FOSSGIS by military institutions will vary, it is recommended that it should be used in collaboration with proprietary GIS software when used in support of military operations. This will ensure that greater access by military personnel to GIS functionalities is achieved.

QGIS is a growing GIS tool and we predict that its use in the military will also grow as employees are trained up in QGIS and their knowledge and experience increase and develop to the same levels they currently have in other software products.

According to Abizad (19 December 2001), a force multiplier is "A capability that, when added to and employed by a combat force, significantly increases the combat potential of that force and thus enhances the probability of successful mission accomplishment".

FOSSGIS has the potential to be a force multiplier in the military!

6 References

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