Using FOSS and Proprietary GIS in Assessing Alien Vegetation Infestation

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Abstract

The Inkomati Water Management Area (WMA) has many competing demands for water and limited water resources. The water used by alien invasive plants could be diverted to other uses if these plants were eliminated. Developing a sound estimate of water use by alien vegetation is therefore an important step in a water-stressed area.

Both FOSS and proprietary technologies were used in assessing water use by alien vegetation in the Inkomati WMA. The initial field data collected and the analysis of remotely sensed imagery were carried out using proprietary systems, as these were established in the organizations that carried out these aspects of the work. FOSS GIS was used to monitor and manage the data collection phase, and in subsequent data analysis.

This paper describes the assessment of alien vegetation as part of the Inkomati Water Availability Assessment Study (WAAS), drawing on remotely sensed imagery and fieldwork to develop a geographic database. The roles of proprietary and FOSS software are discussed, advantages and limitations are noted and some conclusions are drawn regarding the future potential of FOSS GIS.

1. Introduction

This paper reports on the application of FOSS and proprietary GIS in a project assessing alien invasive vegetation infestation, and reflects on the lessons learned from the experience of using FOSS and proprietary GIS. The work was undertaken as part of a water resources study for the Department of Water Affairs and Forestry known as the Inkomati Water Availability Assessment Study (WAAS). The study area covers the catchments of the Crocodile and Komati Rivers. The dominant land uses are forestry in the upper catchment, and irrigation agriculture in the lower reaches. The rapidly growing town of Nelspruit also consumes an increasing share of the water resources, with the result that water available to users in the lower catchment is severely reduced in times of drought.

The study area is shown in Figure 1 below.

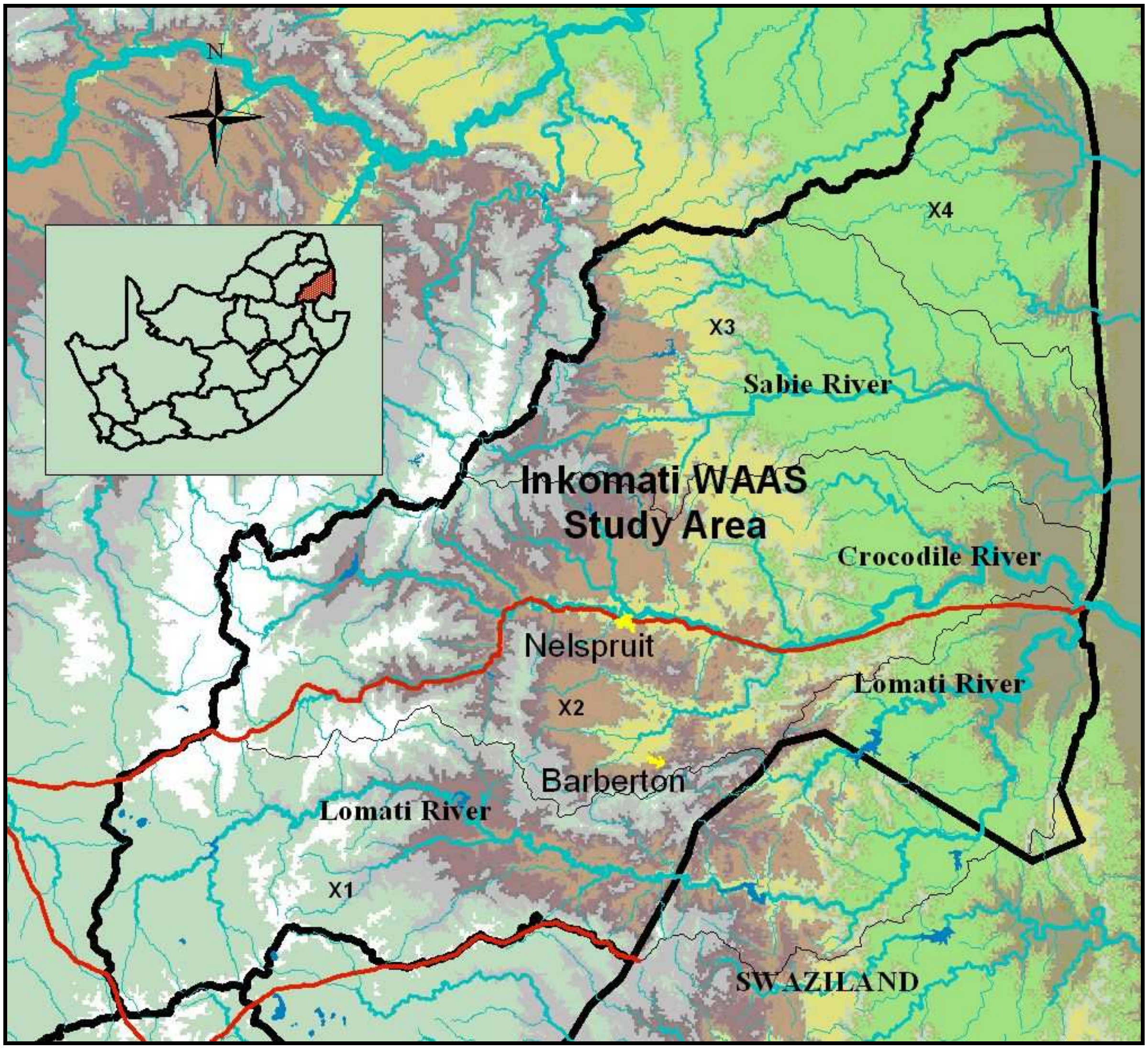

Figure 1 Overview Map of Inkomati Study Area, rendered on Elevation (SRTM)

Invasive alien vegetation was identified as a significant national water user in a seminal study by Versveld *et al* (1998). This work provided technical analysis which could be used as management information by the well know Working for Water Program, which was established in order to remove alien vegetation and make additional water available while providing employment. The national estimates published by Versveld *et al* (1998) were based on the best information available at the time, however more detailed work is required as part of the Inkomati WAAS in order to provide more accurate figures.

2. Approach

The budget for this aspect of the project was limited, and a two-pronged approach was decided on in order to cost-effectively update the estimate of alien vegetation water use: an automated remote sensing analysis approach complemented by a field study. The remote sensing and field work was done by specialist sub-consultants with considerable experience in the assessment of land use by remote sensing and other methodologies, as part of the previous studies for the Department of Water Affairs and Forestry.

The aim of the task was to develop a database of alien vegetation infestation per catchment, divided into zones close to watercourses (riparian areas, where it has almost unlimited access to water) and zones where the growth of alien vegetation is dependent on rainfall. In addition, the vegetation needed to be classified as tall trees, medium trees and tall shrubs because of their different water use.

Geospatial processing technology was applied throughout the project, and particularly in order to:

- Perform the remote sensing analysis, to identify different classes of vegetation.
- Develop a spatial data capture tool to support the field work, to assist in planning the sites to be sampled as well as the capture of the field survey data, and the linkage to co-ordinate values.
- Assess the areas in riparian and non-riparian zones within catchments.

Commercial remote sensing and GIS software was used by the sub-consultants to support their aspects of the work. FOSS GIS was introduced as a project management tool to support the management of the task, and was later explored as an analysis tool in further work on the data. The discussion in this paper is from the perspective of a commercial environment, where GIS is a project tool rather than a core business focus.

Proprietary remote sensing and GIS software (ERDAS and ArcGIS) was used by the sub-consultants to support their aspects of the work, as these were established in these businesses. FOSS GIS was introduced as a project management tool to support the management of the task for the lead consultant, and was later explored as an analysis tool in further work on the data. This paper assesses FOSS GIS for suitability to a commercial environment, where GIS is one among many technical tools rather than a core business focus.

3. Remote Sensing Analysis

The role of the remote sensing analysis was to extract a maximum of information for the entire study area in a cost-effective way. Spot 5 10m resolution data was available for the study area through the Department of Water Affairs and Forestry, and was largely cloud-free. An automated analysis was performed to classify different vegetation categories, which were then summarized per catchment (see Table 1 below).

Table 1 Land use classification from remote sensing versus tertiary catchments

Quaternary	Percentage Area						
	Medium tree	Medium tree / Plantation mix	Plantation	Plantation / Orchard mix	Plantation / Tall tree mix	Tall shrub	Tall shrub / Plantation mix
X11	12.7%	3.4%	9.6%	0.0%	7.1%	0.5%	0.0%
X12	12.6%	4.7%	12.8%	0.0%	10.7%	3.5%	0.1%
X13	20.1%	10.4%	5.3%	0.0%	7.9%	32.1%	23.0%
X14	8.5%	13.6%	4.7%	0.0%	14.8%	11.6%	15.3%
X21	16.8%	18.6%	18.9%	0.0%	11.3%	6.1%	0.2%
X22	7.0%	26.3%	18.1%	11.7%	19.7%	12.4%	9.5%
X23	2.7%	10.9%	5.4%	0.0%	9.4%	12.5%	11.9%
X24	1.4%	5.2%	0.1%	0.5%	2.1%	4.3%	6.0%
X31	11.0%	5.7%	24.3%	82.1%	13.1%	14.7%	15.9%
X32	7.2%	1.2%	0.9%	5.6%	3.7%	2.2%	18.1%

While remote sensed imagery did not directly identify the alien vegetation, unclassified images were used as visual aids to field orientation and interpretation. The classified SPOT5 map products provided spatial information on the extent of woody vegetation cover and plantation forest extent in the catchment. This information was used to both help define the field sampling survey and provide a GIS compatible spatial framework in support of the alien data analysis and reporting.

4. Field Data Collection

The field work involved a rapid appraisal from the vehicle at appropriate points along the road. Where possible, a sample was taken over a broad area from a clear vantage point. Alien plant species occurring were classified, and allocated a prevalence estimate based on the following density classes, Versveld *et al* (1998), – see Table 2 below:

Table 2: Density values used as a guideline for field survey

Density class	Canopy cover	Mid-value	Canopy diameters (metres apart)
Rare	<1%	0.5%	>10
Occasional	1 – 5%	2.5%	3 – 10 +
Scattered	6 – 25%	15%	1 – 3
Medium	26 – 75%	50%	0.3 – 1
Dense	>75%	87.5%	<0.1

On average four samples were taken per sub-quaternary; two within a riparian zone and two outside of the riparian zone. At each site the following additional information was recorded:

- Riparian or non-riparian.
- Site number.
- Latitude and longitude.
- Altitude.
- Broad classification of vegetation type; eg. thicket, grassland, forest etc. and a photographic record.

Route planning was performed for each sub-quaternary. The most suitable road selected from the GIS data set used. This was done in the office prior to the field trip however roads on a map and roads in the field did not always agree. A computer with the back up of a GPS was continuously on (in operation) in the vehicle. It was then possible to verify position within the sub-quaternary at all times and plan the next moves in the field.

All 204 sub-quaternary catchments were assessed. A small percentage (<5%) had only riparian or non riparian data. All sites sampled within forestry plantations were located in open areas between compartments, and every effort was made to exclude commercially planted areas

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5. Alien Vegetation Extent and Water Use

A total of 33 alien plant species were recorded. A few more were observed in the field but were not considered that important for this project because of their low frequency levels and perceived low impact on the water availability within a quaternary. Twelve dominant species were identified according to their level of frequency and density levels within the Inkomati catchment.

Most of the sites surveyed which were allocated densities of 26-75% and >75% represented a small portion of the 300m by 300m sample site. Based on these high recordings, all density values of >75% and 26-75% were scaled down to 6 – 25%. This was done throughout the entire study area.

In order to quantify the data collected (in percentages) and express it in terms of hectares per sub-quaternary, the canopy cover in areas had to be adjusted to equate to a canopy cover of 100%. This was done by reducing the size of the invaded area to its equivalent, had there been 100% cover. For example, an area of 100 ha with a 50% alien-invader cover, equates to an area of 50 ha with a 100% cover. The reduced area (50ha) is described as the ‘condensed’ area (Versveld *et al*, 1998).

The condensed values were then used to estimate riparian and non-riparian infested areas per sub-quaternary. This was aggregated to the tertiary catchment level, and compared to the estimates generated by Versveld *et al* (1998), see Table 3 below.

Table 3: Summary of alien vegetation findings compared to Versveld *et al* (1998)

Tertiary	Inkomati WAAS		Versfeld *et al* Report	
	Area (ha)	Percent	Area (ha)	Percent
X11	*61,928.1*	17.55%	*5,395.0*	*1.53%*
X12	*26,192.6*	10.23%	*2,649.0*	*1.03%*
X13	*32,975.0*	9.10%	*37.0*	*0.01%*
X14	*18,202.9*	12.31%	*2,121.0*	*1.43%*
X21	*40,888.3*	13.23%	*36,699.0*	*11.88%*
X22	*22,115.8*	9.34%	*18,496.0*	*7.81%*
X23	*10,971.8*	6.69%	*12,276.0*	*7.48%*
X24	*3,153.4*	1.17%	*2,794.0*	*1.03%*
X31	*24,827.4*	9.55%	*36,405.0*	*14.00%*
X32	*3,874.8*	2.51%	*6,010.0*	*3.89%*
X40	*48.4*	0.05%	*139.0*	*0.14%*
Totals	**245,178.3**	**9.40%**	**123,021.0**	**5.10%**

The Inkomati WAAS study revealed a substantially higher alien infestation in 2008, compared to the original study by Versveld *et al* (1998). The difference can be attributed in large part to the additional vegetation detected in the X1 secondary catchment. Wattle and gum "jungles" were identified in the field study, particularly in the X11 catchment, which were apparently overlooked previously.

In order to assess the impact of alien vegetation on water availability, the condensed alien vegetation areas were entered into a hydrological model. Catchments with condensed areas of less than 50ha or 1% of the catchment area were discarded. At the time of writing, only a few of the upper catchments had all the required land use and meteorological data prepared so that the model could be run. Initial model runs which simulate the impact of land use in reducing the runoff of rainfall and hence river flow indicate that the reduction due to alien vegetation in the upper catchments varies between 25 and 33% of the total reduction (due to forestry and alien vegetation).

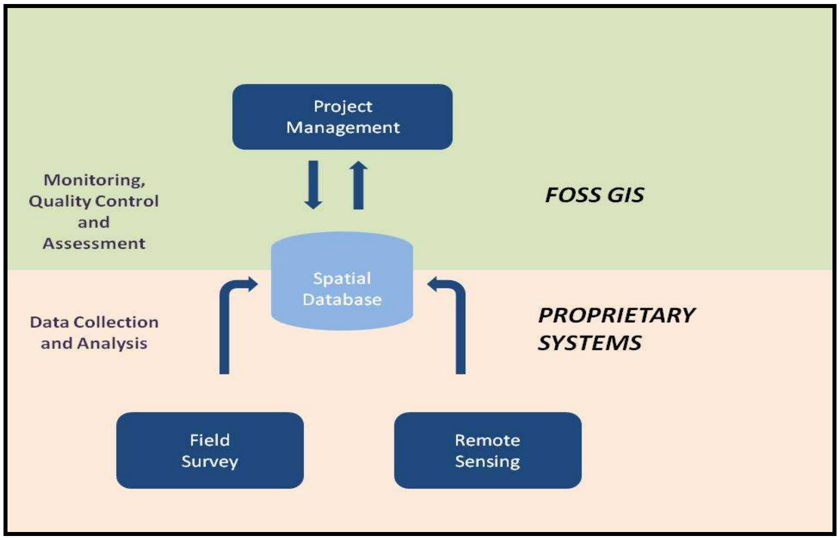
6. FOSS GIS and Project Management

The alien vegetation survey assessment task was managed by lead consultant, under the lead author. The project management of this task involved the following technical steps:

- Review of available information and provision to sub-consultants. Reprojection if necessary.
- Collation of field data, assessment and review of invoices, involving:
    - Setting up a base map, with appropriate symbology.
    - Importing field survey co-ordinates.
    - Mapping of progress
- Review and mapping of final data.

The structure of the project and information flow is illustrated in Figure 2 below.

Figure 2:`Project Structure and Information Flow



ArcGIS was available at the main office. It was installed on a specialized workstation in a common area, which made it unsuitable for casual use. This offered an opportunity to assess FOSS GIS suitability to address the tasks listed above. MapWindow 3.4 was used as the main system, with Quantum GIS (0.11) being introduced later. In addition, GRASS GIS was used in analysis at a later stage.

After three months of ongoing use, it was clear that both products are well suited to meet on-screen mapping, progress monitoring and data query requirements of project management. Both systems support:

- A number of different vector and raster data formats, including shape files and GeoTIFF images used in this study.
- Importation of ASCII coordinates as points (via free plug-ins).
- A number of projections, including the common ones in use in South Africa. Neither support the LO coordinate system though.
- Basic map development (see Figures 3 and 4 below).
- Selection and query of data via spatial or attribute routes.

Both MapWindow and Quantum GIS offer extensibility through their plug-in architectures. In the case of MapWindow using VB or C#, or Python for Quantum GIS. This extensibility sets them apart from freely available commercial offerings such as ArcExplorer and TatukGIS Viewer, and means that they can be adapted to meet particular needs. A range of plug-ins are available for MapWindow and Quantum GIS, which either be used directly or adapted.

Each of the systems have a high level of compatibility with industry standard and other data formats, and the selection of a tool for future similar work depend on the precise project requirements. MapWindow provides more user-friendly projection capabilities, area calculations and vector geoprocessing capabilities. Quantum GIS supports MapInfo data, and offers access to GRASS GIS functionality via a GUI front-end.

7. FOSS GIS and Spatial Analysis

The experience of using FOSS GIS for spatial analysis was more mixed. After several attempts to install GRASS for Cygwin under Windows, the Quantum GIS GRASS Toolbox was used instead. This offers access to a number of GRASS modules through a graphical interface and was far more accessible than the command-line for casual use.

Although there are numerous tutorials on using GRASS on the web, the GRASS workbook (Neteler and Mitasova, 2008) was invaluable in providing an overview of GRASS concepts and commands, and rapidly solving "how-to" questions.

A need arose to analyse riparian areas per sub-catchment. Due to the complexity of the riparian areas shape file, the usual GIS analysis (ArcView-based) software could not be used. This was used as an opportunity to apply GRASS instead. Once the command sequence had been identified, a proof of concept exercise was set up using the Quantum GIS GRASS toolbox. When this had been successfully completed, the intention was to set up a shell script (under MSys) to perform the analysis. This proved to be more challenging than expected, and the GRASS toolbox was used eventually.

While the technical results of the analysis were successful, it was clear that the Quantum GIS front-end is very important in ensuring the successful application of GRASS in a commercial environment. At the moment, this GUI suffers from inconsistencies between commands where some options are available as choices in drop-down menus while similar options elsewhere are made available using a completely different interface element. This is disconcerting to users who rely on the GUI, and should be addressed to build user confidence in the quality of the ho product.

Figure 3: MapWindow Base Map for Inkomati WAAS

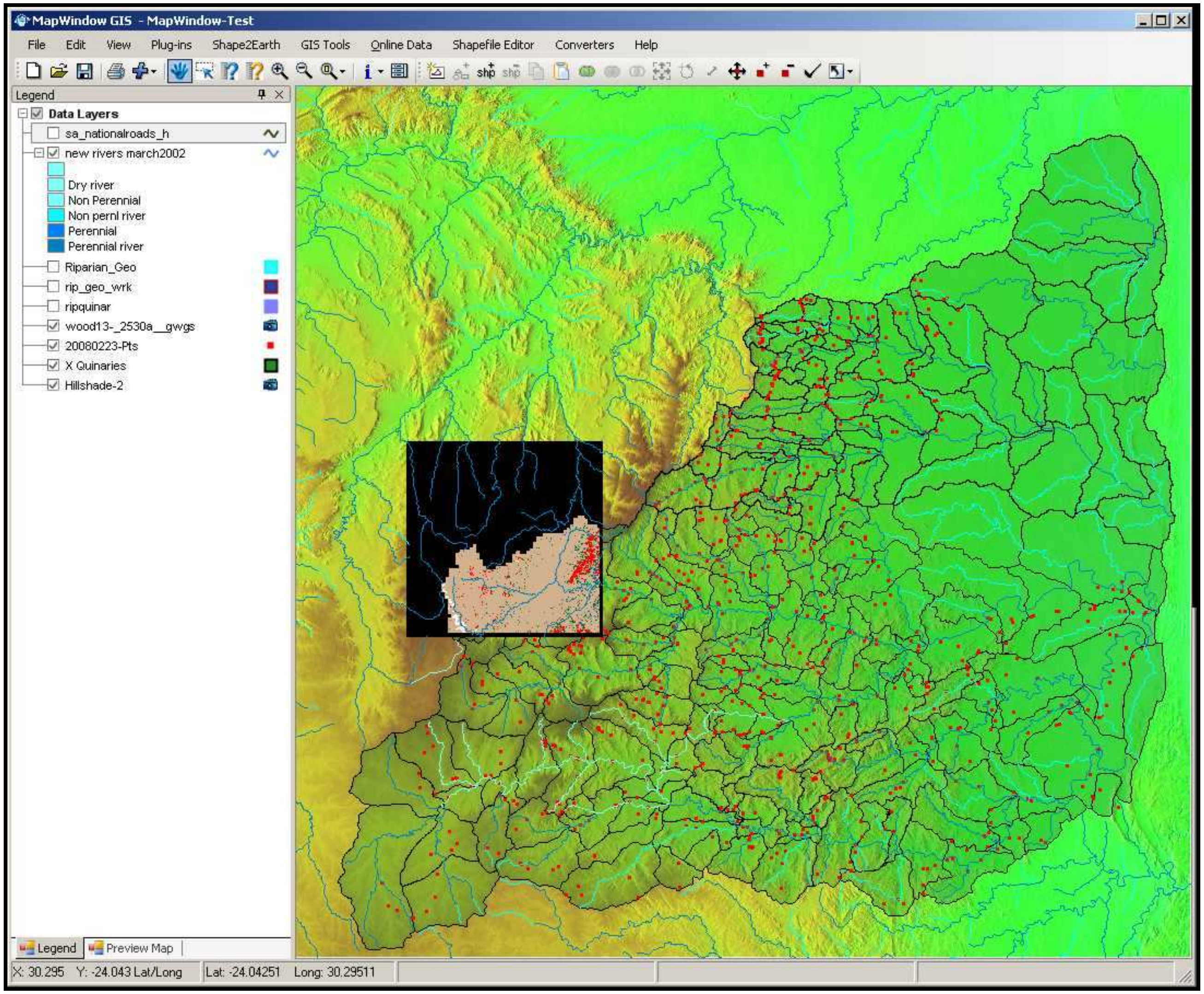
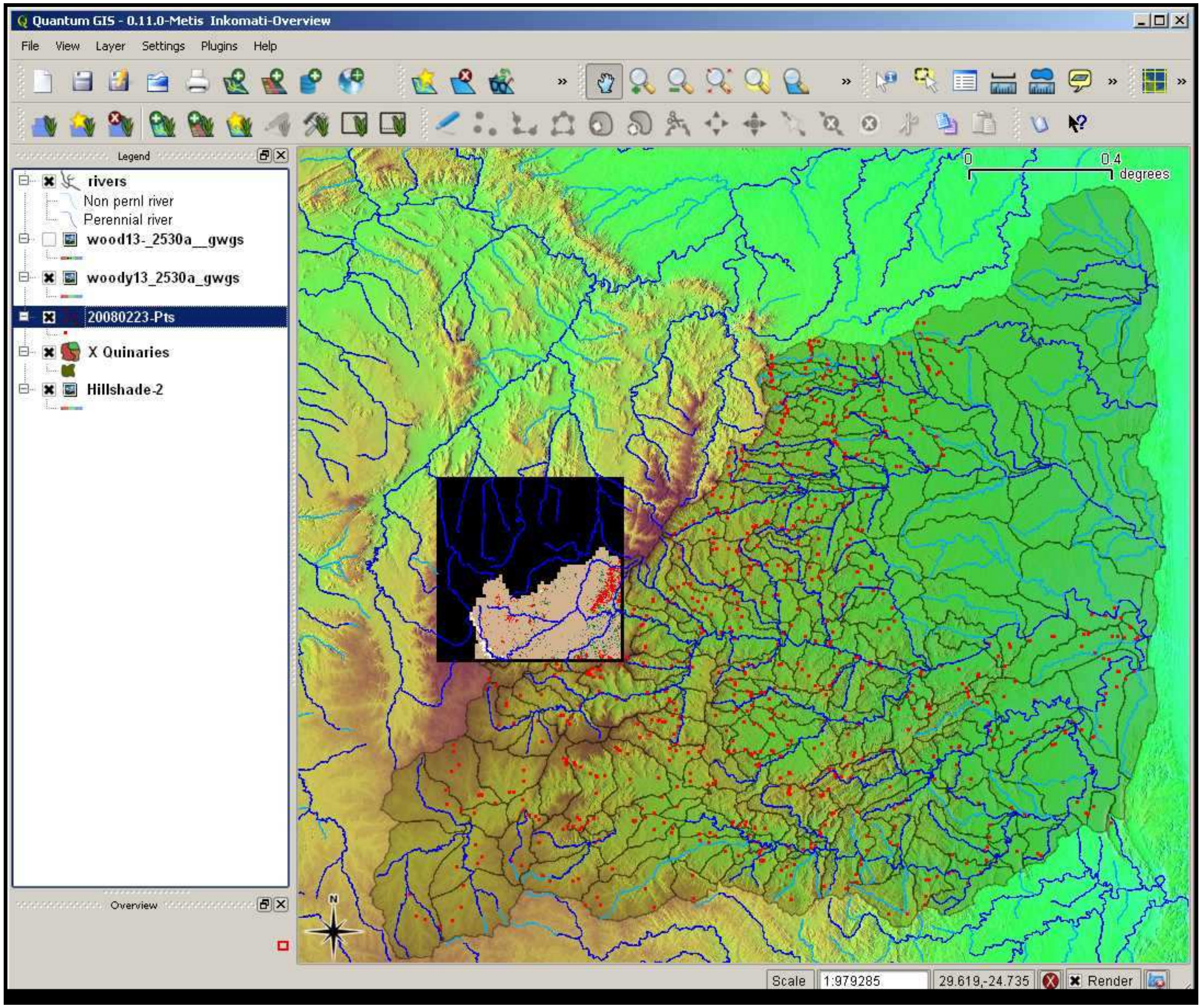


Figure 4: Quantum GIS Base Map for Inkomati WAAS



8. Conclusions

The assessment of alien vegetation for the Inkomati WAAS brought together remote sensing, GIS and field study techniques, to develop an improved geographic database of alien plant infestation in the study area. These techniques may be readily adapted to other catchment areas and clearly illustrate the usefulness of remote sensing data and technology for supporting other environmental/alien plant management surveys and initiatives. Interim results suggest that the impact on water resources is greater than was identified in previous studies. While investigations in this regard are ongoing, it is clear that geospatial technology will continue to play a vital role in supporting water resource management.

The Inkomati WAAS also provided an opportunity to review the readiness of FOSS GIS for the commercial environment. MapWindow and Quantum GIS illustrate two very different approaches to delivering FOSS GIS, drawing on .Net and cross-platform technologies respectively, yet both deliver competent products well suited to project management support. Both systems can be adapted and extended because of their plug-in design and accessible scripting languages, and have lively support communities.

FOSS GIS has progressed tremendously in the last few years, moving from being primarily of academic interest to a serious candidate for commercial applications, particularly where customized functionality is required or budget and/or skilled support staff are limited. A large part of their success is due to the maturity of open source libraries such as GDAL and OGR, which make data exchange with commercial products relatively transparent. Open source map projection libraries such as Proj4 have made a wide range of projections readily available in FOSS software, when only a few years ago this was the domain of high-end proprietary software.

The evolution of FOSS GIS has made more options available to the geoprocessing practitioner, and will surely encourage innovation in the market place. The development of user-friendly interfaces and training and support for advanced systems such as GRASS remain an area requiring more resources if there is to be improved acceptance in the commercial environment. High quality, web-based self-study courses for different levels of user would be a valuable step that could be taken to make the power of FOSS GIS more widely available.

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References

Neteler M and Mitasova H, 2008, *Open Source GIS: A GRASS GIS Approach*, Third Edition, The International Series in Engineering and Computer Science: Volume 773, Springer, New York.

Versveld DB, Le Maitre DC and Chapman RA, 1998, *Alien Invading Plants and Water Resources in South Africa: A Preliminary Assessment*', CSIR Division of Water, Environment and Forest Technology, Stellenbosch, Water Research Commission Report No TT 99/98, Pretoria, South Africa.