# Comparison of remote sensing data sources and techniques for identifying and classifying alien invasive vegetation in riparian zones

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## Abstract

It has been estimated that South Africa will reach the limits of its usable freshwater resources during the first half of the next century if current trends in water use are not reversed. Removing alien vegetation, responsible for the uptake of large amounts of water from riparian zones, is one of the methods of maximising water supply in South Africa. Remote sensing is a cost- and time-effective technique for identifying alien vegetation in riparian zones and remote sensing data can be incorporated into a geographic information system (GIS) which can be used as a tool for the management of riparian zones. In this paper, vegetation identification and classification techniques by using aerial videography, aerial photography and satellite imagery, are assessed in terms of accuracy and cost for a small subcatchment in the KwaZulu-Natal midlands. This was achieved by incorporating the data obtained from aerial videography, aerial photography and ground mapping into a GIS. Accuracies of the different techniques were then examined. Data obtained from satellite imagery were assessed independently using digital image decoding procedures. The costs of each technique were also determined and, together with the accuracy results, used to make recommendations for the most effective manner of identifying alien vegetation in riparian zones. The accuracy results obtained in this study indicate that using manual techniques to identify riparian vegetation from 1:10 000 black and white aerial photographs yields the most accurate and cost-effective results. The least cost-effective data sources were found to be 1:10 000 colour aerial photographs and digital aerial photographs and the least accurate data sources were aerial videography and Landsat thematic mapper (TM) satellite imagery.

## Introduction

It has been estimated that South Africa will reach the limits of its usable freshwater resources during the first half of the next century if current trends in water use are not reversed (Department of Water Affairs, 1986). Clearing riparian zones of exotic invasive vegetation is one of the methods of maximising the water supply in South Africa (Department of Water Affairs and Forestry, 1996a). The *Working for Water* (WFW) programme, a water conservation programme aimed at removing alien vegetation from riparian zones, has been instituted by the Department of Water Affairs and Forestry as an initiative to increase water availability in South Africa (Department of Water Affairs and Forestry, 1996b). In order to plan the removal of alien vegetation from riparian zones, detailed mapping of the catchments has to be undertaken.

Remote sensing is the observation of objects and features without contact and includes mapping and digital image processing techniques using aerial photography and satellite imagery. Remote sensing provides up-to-date, detailed information about land condition and land use, and uses instruments mounted on aeroplanes and satellites to produce images of the Earth's surface (Perryman, 1996; Evans, 1997). Remote sensing provides spatial data that can be incorporated into a geographic information system (GIS) which facilitates the management of water resources, land use and land cover as well as urban planning (ESRI Inc., 1990). The primary objective of this study is to identify and assess different remote sensing data sources that are applicable to mapping alien vegetation in riparian areas. These data will enable the removal of such vegetation in efforts to increase streamflow and conserve water. This objective was achieved by documenting the comparison of remote sensing data sources including aerial videography, aerial photography and satellite imagery. Previous studies (Van Wyk, 1997) have compared different satellite data sources for mapping alien invasive vegetation, particularly wattle, although density of such vegetation and other types of riparian vegetation have not been classified. Conventional aerial photography as a data source was also not assessed. Thompson (1997) also details large scale (1:250 000) land cover mapping of South Africa using 'Spacemaps' derived from Landsat TM imagery.

## Materials and methods

### Study site

Subcatchment No. 18 of the Midmar catchment, located between 29° 32' 02" and 29° 38' 25" South and 30° 03' 30" and 30° 08' 15" East, was chosen as the study site. This catchment is a subcatchment of the Mgeni catchment and is located in the KwaZulu-Natal midlands, 30 km north of Pietermaritzburg. The study site lies immediately south west of the Midmar Dam and is approximately 56 $km^2$ in size (Armstrong, 1997) (Fig. 1), thus small enough to facilitate ground mapping. All major land-use categories, for example afforestation, pasture, and dryland farming, are repre-

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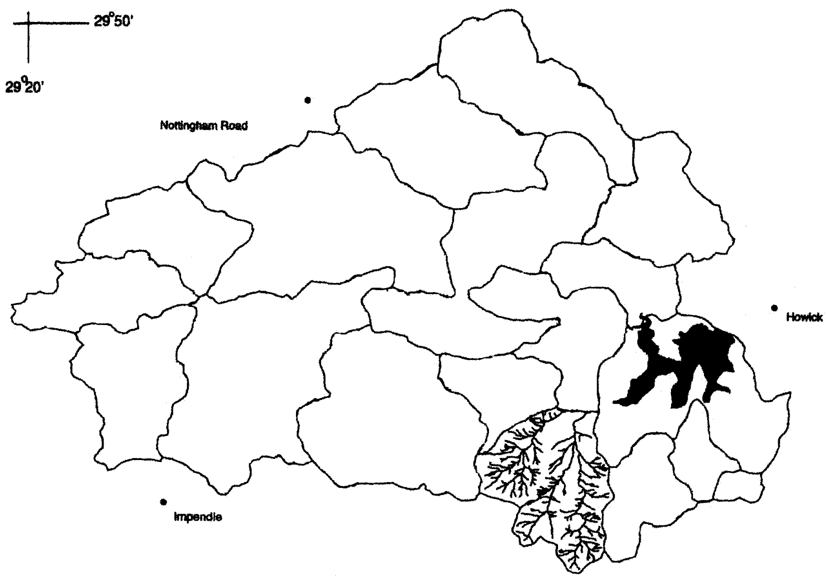


***Figure 1***
*The study site showing Subcatchment No. 18 of the Midmar catchment in the KwaZulu-Natal midlands, South Africa*

sented in this subcatchment. Vegetation types include large tracts of commercial pine and *Eucalyptus* forests as well as smaller tracts of indigenous forests. The area also contains natural grasslands occurring on the northern slopes. The area is dissected by three main tributaries of the Gqishi River which feed into the Midmar Dam.

Data in the form of aerial photographs and satellite imagery were available and consultants have completed an aerial videography study of this catchment. A digital coverage of the rivers in the Midmar catchment was obtained and opened in ArcView (ArcView 3.0, 1997). The subcatchment boundaries were overlain onto the river coverage and Subcatchment No. 18 was isolated. Subcatchment No. 18 was converted to a shapefile, which formed the basis for all the GIS manipulations. The initial collection of field reference data was carried out by means of several visits to the study area and visual interpretation of the vegetation in the riparian zones, that was mapped directly onto 1:50 000 maps by eye. The following classes were used for classifying the riparian zone vegetation: agriculture; cleared commercial forestry; grassland; indigenous forest; pasture; scrub; dense alien vegetation; medium alien vegetation and sparse alien vegetation.

## Aerial videography

A CCD non-digital video camera was used to capture the aerial videography data. Riparian zone vegetation was recorded at an altitude of 2 743.2 m, which gives a resolution of a 2.5 m pixel size. The outline of the catchment was drawn onto 1:50 000 maps. The maps were first rectified in ERDAS-IMAGINE (Coleman, 1997) and then imported into ArcView (ArcView 3.0, 1997) to facilitate a GIS. The video recording was run on a monitor next to the computer and paused on every frame. The user then estimated the location of vegetation on the 1:50 000 map and digitised the land-use polygon directly over the map using features occurring on the map as a reference (Coleman, 1997).

## Aerial photography

Black and white aerial photographs at two scales, 1:30 000 and 1:10 000, were used as data sources and obtained from the Chief Directorate: Surveys and Land Information at the Department of Land Affairs, Mowbray, South Africa. The black and white aerial photographs were captured in 1996, thus the vegetation depicted was deemed to be an accurate reflection of the present ground cover. By mosaicking four aerial photographs together, it was possible to get a complete coverage of the study area.

The colour photographs were captured in 1994 and comprised an area of approximately 22.40 $km^2$ which is located in the north-western region of the study site. A transparent sheet, on which the riparian zones of Subcatchment No. 18 were marked, was printed at scales of 1:30 000 and 1:10 000. These transparencies were laid over the mosaicked aerial photographs and the riparian zone vegetation was traced directly onto the transparencies using manual photo-interpretation techniques. This information was then digitised into a GIS using ArcView (ArcView 3.0, 1997). This was achieved by manually editing the attribute table associated with the Subcatchment No. 18 shapefile.

## Landsat TM satellite imagery

A winter digital Landsat 5 TM satellite image, comprising bands 2, 5 and 7, captured on 07/06/95 was used as a data source which was decoded using ERDAS (ERDAS-IMAGINE, 1997) software. Although bands 3, 4 and 5 are conventionally used for vegetation mapping, these were not available as a previously ordered image was used due to budget constraints. However, as band 2, with a wavelength of 0.52 to 0.6 µm, corresponds to the green reflectance of healthy vegetation and band 7, which has a wavelength of 2.08 to 2.35 µm and detects in the mid infra-red range, is able to determine vegetation moisture content (ERDAS, 1995), the image was still deemed suitable for use as a broad vegetation mapping tool. The 12 km x 12 km image of the study area was clipped from the original image using ARC/INFO (ARC/INFO 7.0.4, 1997) and the RECTIFY command. This enabled the classifying time and memory storage space required to be reduced. Unsupervised classification was performed on the crisped, clipped image using the ISODATA procedure. Supervised classification was performed on the same image with random training samples digitised with the AOI TOOLS feature. The desired classes assigned to the image undergoing supervised classification were: water; commercial forests; natural scrub/indigenous forest; pasture; agriculture; grassland and cleared commercial forests. The image was crisped in an effort to view the riparian vegetation more clearly. The crisp filter, using the SPATIAL ENHANCE/CRISP function, sharpens the overall scene luminance without distorting the interband variance content of the image. This enhancement reduces blur due to atmospheric haze or rapid sensor motion (ERDAS, 1995). Forty classes were chosen for the unsupervised classification. This number was chosen after an initial 100 classes were set and then generated classes of obviously similar land-cover types were merged together. Forty classes were found to give satisfactory distinction between different land-cover types but also ensured that the same land-cover type was represented by a single class. Maximum iterations was set at twenty-four, as suggested in the ERDAS field guide (ERDAS, 1995), and a convergence threshold of 0.95 was stated.

### Accuracy assessment

A spreadsheet was created in Microsoft Excel (Excel 5.0, 1993) to compare the attribute tables from each coverage created in ArcView (ArcView vers. 3.0, 1997). This was achieved by comparing each individual section of the riparian zones classified from each different data source to the section of riparian zone classified from ground mapping. The attributes from each ArcView coverage were exported as a database file. The riparian zone attribute column from each coverage was cut and pasted into a spreadsheet for comparison with the riparian zone attribute column created in the ground mapping coverage. The accuracies calculated were based on stream lengths.

Different accuracy assessments were also performed on both the unsupervised and the supervised classified Landsat TM image using ERDAS Imagine (ERDAS-IMAGINE, 1997). This was carried out because the image was too coarse (25 m pixel) to assess just the riparian zones, which extend 30 m either side of the river course, however a general indication of the overall accuracy of the entire satellite image was thought to be useful.

## Results

Table 1 summaries the accuracy results obtained in this study while Table 2 compares the different costs for each remote sensing data source that was used to identify alien invasive vegetation in the riparian zones of Subcatchment No. 18.

The results of the field mapping exercise, carried out to get an accurate representation of the vegetation occurring in the riparian zones of Subcatchment No. 18, was assumed to be 100% correct and was the benchmark against which information derived from aerial videography, aerial photography and satellite imagery were compared. The results of the aerial videography study showed that aerial videography has an accuracy of 14.93%. The cost of this procedure was R41 875.00 excluding VAT, which is equivalent to approximately R45.27/km$^2$ of riparian zone, excluding VAT (Umgeni Water, 1997). Vegetation classification from 1:30 000 black and white aerial photographs revealed an accuracy of 56.85% and cost R7.59/km$^2$ (Clarke, 1997), while the results of the vegetation classification from 1:10 000 black and white aerial photographs had an accuracy of 68.74% and the cost was R19.93 per km$^2$ (Clarke, 1997). Only the northern portion of Subcatchment No. 18 was classified from the colour 1:10 000 aerial photographs due to unavailability of a complete coverage of colour aerial photographs. The accuracy results for the smaller area were interpolated to the entire study area, which showed that interpreting 1:10 000 colour aerial photographs has an accuracy of 57.61% with a cost of R175.90/km$^2$.

The accuracy assessment performed on the unsupervised classified image revealed an accuracy of 52.5% while the supervised classified image had an accuracy of 52.0%. It must be noted that the accuracies obtained from both classification techniques apply to land use in general over the whole study area and not specifically to riparian zones.

**TABLE 1**
**A COMPARISON OF THE ACCURACY OF THE DIFFERENT REMOTE SENSING TECHNIQUES**

| Data source | Accuracy of vegetation classification |
|---|---|
| Ground mapping | 100% |
| Aerial videography | 14.93% |
| 1:30 000 black and white aerial photograph | 56.85% |
| 1:10 000 black and white aerial photograph | 68.74% |
| 1:10 000 colour aerial photograph | 57.61% |
| Unsupervised classification of digital image | 52.50% |
| Supervised classification of digital image | 52.00% |

**TABLE 2**
**A COMPARISON OF THE COST OF DIFFERENT REMOTE SENSING TECHNIQUES**

| Remote sensing data source | Cost for riparian zones |
|---|---|
| Aerial videography | R45.27/km$^2$ |
| 1:30 000 black and white aerial photography | R7.59/km$^2$ |
| 1:10 000 black and white aerial photography | R19.93/km$^2$ |
| 1:10 000 colour aerial photography | R175.90/km$^2$ |
| Landsat TM imagery | R6 000.00/8 100 km$^2$ (90 km x 90 km) =R0.74/km$^2$ |

## Discussion and conclusions

Aerial videography is a new technique that has been incorporated into traditional remote sensing techniques in order to reduce the time required for data processing. Aerial videography has been recently used by various companies. However, the results of the technique have not been assessed and therefore the accuracy obtained is unknown (Thomas, 1997).

The classification of vegetation from all the remote sensing techniques was subjective, as distinguishing between sparse, medium and dense alien vegetation as well as pasture, grazing and indigenous forests by eye was based on opinion alone. The method of ground mapping employed was effective, although time-consuming, as mapping 8.431 km$^2$ of riparian zones required approximately 30 h by one person. Aerial videography had an accuracy of 14.93% when comparing the riparian vegetation results obtained by consultants to Umgeni Water to the riparian zone vegetation observed from ground mapping. This accuracy is very low, but can be explained by a slightly different classification system that was employed for ground mapping. The consultants used fewer vegetation categories than were used in this study to record the riparian vegetation. Since aerial videography is thought to be an accurate technique, these accuracy results are not a true reflection of the potential for identifying vegetation in riparian zones. The spatial resolution of the image obtained from a CCD non-digital video camera is not as high as that of film, which may also have contributed to the overall low accuracy obtained.

Classifying alien vegetation in the riparian zones from aerial photographs was not time-consuming. Approximately six hours were required to identify the riparian vegetation and incorporate the data into a GIS. The same amount of time was taken when identifying riparian vegetation from the 1:30 000 black and white, 1:10 000 black and white and 1:10 000 colour aerial photographs. While it was expected that the 1:10 000 black and white aerial photography would be more accurate than the 1:30 000 black and white aerial photographs due to the higher resolution, the 1:10 000 colour aerial photographs were expected to yield greater accuracy than the results of this study show. The lower than expected accuracy of the colour aerial photographs can be attributed to the fact that the colour aerial photographs were commissioned and taken in 1994 and are thus more than three years out of date. Not only does the vegetation type change over a number of years, as pastures can become planted with crops and commercial forests encroach on indigenous forest, but also the alien vegetation extent changes, as sparse alien vegetation grows in size and after three years, if not cleared, will become dense (closed canopy) alien vegetation.

The accuracy results from all of the aerial photographs were not as high as expected. This can nevertheless be explained by the large degree of subjectivity involved when determining vegetation types. In addition, the black and white aerial photographs were taken in 1996 and the ground mapping was only carried out in late 1997, almost eighteen months later. During this time, sparse alien vegetation may have become more dense, resulting in the ground mapping classifying those riparian zones as medium or even dense alien vegetation.

Overall land cover was mapped from the Landsat image because the pixel size of 25 m was too coarse to determine riparian vegetation, which is considered to extend 30 m either side of the water course. Satellite imagery such as Landsat TM should only be used to identify broad-scale land use and land cover. The results obtained from the satellite study did not show Landsat TM imagery to be a reliable data source for in-depth vegetation classification. From the results of this study, it is apparent that using 1:10 000 black and white aerial photographs, obtained from the Department of Land Affairs in Mowbray at a cost of R19.93 per $km^2$, provides cost-effective and accurate results for identifying riparian vegetation. All the other remote sensing data used in this study provide acceptable results; however, the satellite imagery provided images of very low resolution, despite the low cost, and colour aerial photography proved too expensive for the average of accuracy results obtained. Aerial videography does provide a reasonably accurate reflection of the vegetation cover in riparian zones, and although more expensive than black and white aerial photography, it is more cost-effective than colour aerial photography. It is recommended that if aerial videography be used for future riparian vegetation mapping, the vegetation classification system be modified to include categories such as cleared afforestation, indigenous forest and pasture. Using 1:10 000 black and white aerial photography as a data source and manually identifying riparian vegetation is the recommended procedure, as this technique yields accurate results, is cost-effective in terms of labour and data acquisition costs and is not time-consuming.

A combination of data sources and techniques may also have provided better results then the individual data sources used in this study. Combining the spatial resolution of the 1:10 000 black and white aerial photographs with the spectral resolution of the Landsat TM image is possible although not performed in this study. Mapping using this type of combined data should be explored in further studies.

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