Spectral analysis of 8-band WorldView-2 data for monitoring regional vegetation condition: mapping of alien invasive plants species in the West Coast

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Abstract

The Western Cape province of South Africa is mainly covered by fynbos. Fynbos is native vegetation which lies within the Cape floristic kingdom, and is well known for its diversity, endemism and global botanical significance. Unfortunately, extensive areas of the primary indigenous fynbos have been lost due to the invasion of alien plant species. Hundreds of endemic species are threatened by this alien invasion while getting rid of these invasive plants is difficult due to their rapid spread measures are being put in place help understand their distribution across the region both by the private and public sector. However, most approaches have proven to be very costly both in financially and in labor terms. Therefore more effective tools are being sort after for effective environmental monitoring. The crucial issue affecting most monitoring exercises has been the lack of accurate recognition and mapping of current distribution of invasive plants and hence early detection of new occurrences. In this study, 8 bands, very high resolution satellite imagery from the WorldView-2 sensor was used for evaluating the impact of these invasive alien plants in the West Coast region of the province. Results from the image analysis and classification showed that high resolution imagery can be used in understanding the spatial distribution of these alien species.

Keywords

remote sensing, alien vegetation, environment, sustainable

Introduction

The Western Cape province of South Africa is an area of global biodiversity, significant for its unique, endemic vegetation, named fynbos. Unfortunately, extensive areas of these primary indigenous fynbos have been lost due to numerous factors, but prominently due to invasive alien plants species [1]. Alien species compete with indigenous species for resources necessary to their growth such water and nutrition. This not only does it affect the ecological balance of natural ecosystems but also has resulted in reduced water run-off in the region. The pests and parasites that would control these species of plants are not present and therefore they continue to grow and spread with very few obstacles [2]. The suitability of remote sensing data in ecological studies has frequently been documented, however, the launch in 2009 of the WorldView-2 satellite, 8-band multispectral imagery created the possibility for precise mapping and monitoring of various groups of vegetation at regional scale [3]. In this study we aimed at mapping these invasive species by applying complex remote Sensing techniques using high resolution imagery from WorldView-2 satellite. The study aims at inspiring an increase in the use of high resolution imagery in similar studies.

The successful use of satellite images can be an important contribution to support decision-making regarding the prevention, eradication and control of invasive species and other environmental and agricultural issues.

Study area

The study area is a stretch of land on the West Coast region bounded by Rietvlei wetland area on the south and Melkbosstrand Golf Course on the North and Cape Farms on the east (Fig. 1). Geographically the area is demarcated by longitude 18°26’ – 18°32’ and latitude 33°44’ – 33°50’ with an extent of approximately 120 km². The endemic flora of this region consists of Cape Flats Sand Fynbos (CFSF) and is statutorily conserved in Blaauwberg Conservation Area (Fig. 1). Majority of the land in the neighborhood is occupied by urban and industrial estates, farmlands and large rural area being overgrown by various vegetation species, including numerous invasive alien plants. The CFSF is particularly affected by the spread of these alien species, particularly species of Australian acacia, hakea and eucalyptus, and pines from the northern hemisphere. Many of these trees are considered ecosystem transformers as they out-compete the indigenous vegetation and alter ecosystem processes, such as nutrient cycling, fire and the hydrological regime [1]. In this study four vegetation
species were selected as a target of remote sensing analyses namely: pine tree, eucalyptus tree, extremely invasive acacia saligna (Port Jackson willow) and native fynbos vegetation.

**Fig. 1: Study location map.**

**Methods and data**

This study was using WorldView-2 imagery using bands 1 to 8 acquired around October/November 2013. The eight bands used cover the visible to near-infrared range of the electromagnetic spectrum (EMS). These bands are narrowly focused on a particular range of the EMS and thus are more sensitive to particular features on the ground [4].

Table 1 shows these eight bands and the wavelengths covered by each. These digital images were processed using Erdas Imagine 2014 and 2015 software packages.

<table>
<thead>
<tr>
<th>Band name</th>
<th>Centre wavelength (nm)</th>
<th>Lower band edge (nm)</th>
<th>Upper band edge (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panchromatic</td>
<td>627</td>
<td>447</td>
<td>808</td>
</tr>
<tr>
<td>Costal blue</td>
<td>427</td>
<td>396</td>
<td>458</td>
</tr>
<tr>
<td>Blue</td>
<td>478</td>
<td>442</td>
<td>515</td>
</tr>
<tr>
<td>Green</td>
<td>546</td>
<td>506</td>
<td>586</td>
</tr>
<tr>
<td>Yellow</td>
<td>608</td>
<td>584</td>
<td>632</td>
</tr>
<tr>
<td>Red</td>
<td>659</td>
<td>624</td>
<td>694</td>
</tr>
<tr>
<td>Red edge</td>
<td>724</td>
<td>699</td>
<td>749</td>
</tr>
<tr>
<td>NIR 1</td>
<td>833</td>
<td>765</td>
<td>901</td>
</tr>
<tr>
<td>NIR 2</td>
<td>949</td>
<td>856</td>
<td>1043</td>
</tr>
</tbody>
</table>

*Table 1: WorldView-2 spectral band edges and centre wavelengths [5].*

The four primary multispectral bands include traditional blue, green, red and near-infrared bands. Four additional bands include a shorter wavelength blue band, centred at approximately 427 nm, called the coastal band for its applications in water colour studies; a yellow band, a red edge band strategically positioned at the onset of the high reflectivity portion of vegetation; and an additional, longer wavelength near-infrared band, which is sensitive to atmospheric water vapour [5].

In the near infrared (NIR) region, the reflectance is much higher than that in the visible bands due to the cellular structure in the leaves. Hence, vegetation can be identified by the high NIR but generally low visible reflectance [5]. The yellow and red edge bands captured by WorldView-2 satellite provided additional source of
information on the regional vegetation by providing a means to distinguish between various types of flora, e.g. separate coniferous from deciduous trees or even identification of tree species within the forest [5]. The red edge region denotes an abrupt change in reflectance between red and near infrared bands. It is a boundary between absorption by chlorophyll and a high reflectance in the NIR region. Also the red edge position (REP) is used to estimate the chlorophyll content of leaves or a canopy. The shape of the reflectance spectrum was used for identification of certain species. The reflectance of the tree canopy is not only dependent on the leaf properties but also affected by other factors such as tree health and age, crown density, leaf size, shape and inner structure.

Pre-processing

Satellite images were pre-process and analysed using Erdas Imagine software because of its powerful capabilities in handling these large datasets its various techniques. Pre-processing techniques are used to reduce geometric and radiometric variations in images. Geometric correction technique was applied based on control points from a pre-registered image to topographically correct the images. The panchromatic band (0,46 m) was used to enhance the spatial resolution of the multi-spectral datasets using the Brovey Transformation technique. The Brovey Transform was developed to visually increase contrast in the low and high ends of a histogram. In preparation for the analysis a field visit was done in which various sites of possible alien vegetation species were surveyed. The sampling sites for the eucalyptus trees, pine trees, Port Jackson willow and unclassified fynbos were demarcated and mapped.

Image analysis

- Spectral unsupervised classification
  The multispectral classification is the process of sorting pixels into a finite number of individual classes based on their reflectance values. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to that criterion. Unsupervised classification was performed using the Iterative Self-Organising Data Analysis Technique (ISODATA) algorithm to the image. The ISODATA method uses minimum spectral distance to assign a cluster to each candidate pixel. The process begins with a specified number of arbitrary cluster means or the means of existing signatures, and then it processes repetitively, so that those means shift to the means of the clusters in the data. In this study 20 clusters were defined which further reduced to ten clusters. This variation allowed us to map possible clusters of alien vegetation species. Fig. 2 shows the final reduced image.

![Fig. 2: Vegetation map of the study area accomplished from image indices and classification processes.](image-url)
On analysis these clusters correlated with geo-location of the field trip sampling sites were grouped in four definite classes: eucalyptus, Port Jackson willow, pine and fynbos. The remaining classes were identified as water, bare field, agriculture, irrigated grass and wetland (Fig. 2). Pixels of human-made structures were ignored in the analysis. It must be noted that obtained classification categories are relatively approximate, specifically the pine group, which include other trees of similar spectral parameters. The reflectance spectrum of the designated pixels of WorldView-2 images overlying sampling sites was plotted against each spectral band as shown on the pictures (Fig. 2). While eucalyptus and Port Jackson willow significantly vary from other woody species, pine tree, palms and other kinds are quite similar in terms of spectral response (Fig. 3). These spectral response curves correlated with the sites visited.

Fig. 3: Pictures of studied plants and curves of spectral profiles of the correlated pixels in the satellite image.

A further analysis of the spectral response curves showed that the red-edge range of spectral profiles of all species show an abrupt change in reflectance. However, the spectral profile of eucalyptus increases significantly to 0.6, while pine tree and fynbos curves stay at the lower range. The curve of the Port Jackson willow shows significant reflectance in the visible range than other plants and it increases significantly at the red-edge band as well (Fig. 4).

Fig. 4: Spectral signatures of studied vegetation types.
The eucalyptus curve is steeper than the curve of Port Jackson willow, along with a shift of the red edge of the absorption to shorter wavelengths. This shows that eucalyptus Re/R ratio is higher than Port Jackson willow. It was also observed in the earlier publications [4] that because of increased chlorophyll content the red edge peak moves to longer wavelengths. This is called “red shift” and its value varies with plant type and can be used to distinguish between plant species. Port Jackson willow, characterised by extremely invasive nature, grows quickly and in most cases specimens are young with lower chlorophyll contents. Eucalyptus trees are mostly matured, tall trees with dense canopies thus their spectral profile show normal curve typical for healthy vegetation.

- **Red/NIR index analysis**

Because of ratio of NIR to red light in eucalyptus measurements is lower than in the case of Port Jackson willow. The R/NIR index was implemented for the basic separation of these two plants in the image. The thematic output of this calculation displays pixels of value 0.1 – 0.2 for the eucalyptus pixels and 0.3 – 0.5 for Port Jackson willows pixels (Fig. 5).

![Image of Ratio Vegetation Index (RVI) with eucalyptus and Port Jackson willow pixels](image)

*Fig. 5: Picture of Ratio Vegetation Index. RVI (Red/NIR). Green and red pixels: eucalyptus (value 0.1 – 0.2); pink and brown pixels: Port Jackson willow (value 0.3 – 0.5).*

**Results**

Using 8-band image in classification technique allowed creating highly accurate and detailed vegetation cover map of the Cape Town west coast with the special interest for alien trees invading Cape floral kingdom’s native fynbos vegetation. WorldView-2, 46 cm panchromatic and 1,8 m multispectral resolution, 8-bands image is the optimal solution for detecting and mapping the invasive alien plants. The two new sensors: red edge and yellow enhance our ability to distinguish between various plant types and thus can be successfully used for the many environmental, agricultural and other location based services.

**Conclusions**

The results from this study showed that WorldView-2 higher resolution imagery can reliably be used to detect and map different plant species. For the mapping of new infestations as well as rate of invasion by alien species a time series analysis change detection analysis needs to be done. With a proper initial survey of the region environmentalists will be able to apply a series of remote sensing analysis including indices, image classification and change detection techniques to the subsequent images acquired yearly in the same time of the year in order to quickly and effortlessly monitor alien invasive plants in Cape Town area.
References

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