A new approach to determining impacts to Groundwater Dependent Ecosystems

By Ben Roberts[1]

Abstract

This paper reviews the historical use of remote sensing technology in modelling and monitoring biodiversity and ecosystem health. It presents a review of how these approaches can be applied to Environmental Impact Assessment (EIA) studies by looking at a case study involving the identification of Groundwater Dependent Ecosystems (GDEs) associated with a quarry expansion project in south-eastern Australia. Groundwater Dependent Ecosystems are considered to be terrestrial or aquatic ecosystems that utilise groundwater resources.

Since the Millennium drought there has been an increased level of research into GDEs. This has led to a greater understanding of how they interact with, and their criticality to environmental processes. At the same time, competing demands on groundwater resources resulting from agriculture intensification and domestic water supply have never been greater. Groundwater Dependent Ecosystems themselves are also at threat from pressures of urban sprawl and the recent eastern Australia ‘infrastructure boom’.

These threats have been acted on by national and provincial governments in countries across the southern hemisphere to identify the location of GDEs in order to regulate their use and impact. This has caught many impact assessors off guard, not knowing how to identify or monitor GDEs. As pressures grow on GDEs around Australia and indeed around the world, this area of study will undoubtedly be an area of increased interest to EIA practitioners and regulatory authorities alike.

Introduction

As remote sensing technologies continue to develop and advance over time, remote sensing is quickly becoming a tool that is regularly used by environmental and agricultural scientists to measure and model ecological parameters. The use of remote sensing for biodiversity and conservation management has been categorised by Turner *et al*. (2003) into direct and indirect approaches. The former involves identifying individual organisms, species assemblages, or ecological communities whilst the latter approach includes identifying biodiversity trends through environmental parameters as proxies. The indirect approach has been explored further by considering the use of remote sensing in the context of Environmental Impact Assessment (EIA). This is done through a case study which has

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sought to identify the presence or absence of GDEs in south-eastern Australia as part of a basalt quarry expansion project. Groundwater Dependent Ecosystems are considered to be terrestrial or aquatic ecosystems that utilise groundwater resources. As demands for earth resources increases on the back of what is being termed as an ‘infrastructure boom’ in eastern Australia, as well as existing pressures on groundwater resources, this area of study is likely to increase over time.

Traditional ecological applications of remote sensing

Satellite remote sensing has an inherent benefit of capturing imagery from broad spatial extents that cannot be collected using field-based methods. This in-turn provides environmental scientists with the ability to view and interpret the earth’s surface to identify an array of ecological trends and measurements. When combined with other environmental parameters such as soil type, slope and aspect, this provides ecologist and biodiversity managers with the ability to directly and in-directly identify and model ecological features and patterns. This includes such uses as classifying the landscape into habitats or monitoring board scale landscape change over time such as woodland or grassland extents. Kerr and Ostrovsky (2003) have categorised the traditional uses of remote sensing for biodiversity and conservation management into the following three categories.

- Land cover classification: used to estimate the variety, type and extent of land cover throughout a landscape. When applied with other ecological and physiological parameters, this approach can be used to model landscape attributes such as vegetation extent, vegetation types, habitat types and derivatives from these core data sets. This approach aligns with Turner *et al*. (2003) indirect method of biodiversity modelling through remote sensing of environmental parameters.
- Integrated ecosystem measurements: used to monitor ecosystem function over large spatial scales. These large scale applications are notably used for measuring impact of human-caused change or large environmental change such as climate change when coupled with meteorological and soil data. Specialist programs have been developed to capture information from hyperspectral satellites to provide insight to plant production rates for crops and plantations.
- Change detection: used by researchers to detect biophysical and habitat change over time.

Besides ecological uses, remote sensing imagery has been applied to several other industries including precision agriculture, horticulture and forestry providing more efficient applications of labour.

Environmental datasets derived from remote sensing outputs are regularly used in contemporary EIA. These datasets form integral information sources for environmental desktop studies which seek information on key environmental parameters such as extents and types of indigenous vegetation and species habitat distribution.

How Remote Sensing works

Broadly, remote sensing involves the process of making earth observations remotely from satellite or aerially including Unmanned Aerial Vehicles (UAV). Data collected from specialised cameras or sensors allow captured images to be manipulated and analysed to make observations of spatial trends and patterns. Most commonly remote imagery is used to view the earth under normal light. Remote imagery becoming more common includes LiDAR, thermal infrared, near-infrared (NIR) and short wave infrared using radar, thermal and multispectral sensors. The case study provided later describes the application of a model known as the Normalised Density Vegetation Index (NDVI) that views imagery taken in the NIR light range using multi-spectral sensor.

The NDVI model is most commonly used to indicate plant health or productivity. This process works by plants absorbing and reflecting wavelengths of light as part of the photosynthesis cycle. The pigment in plant leaves, chlorophyll, strongly absorbs visible light (from 0.4 to 0.7 µm) for use in photosynthesis. Conversely, the cell structure of the leaves strongly reflects NIR light (from 0.7 to 1.1 µm). Therefore, the more leaves present on a plant or the more actively a plant is growing, the greater NIR signature. In the case study provided below, we use the NDVI model to indicate growth seasonality of a eucalypt Damp Forest vegetation type in south-eastern Australia as a proxy for determining the presence of a GDE.

Limitations of Remote Sensing for EIA

The spatial resolution and orbit time can be a limiting factor of satellite remote sensing technology. Orbit and image resolution for MODIS and Landsat satellites is listed below.

- MODIS satellite provides imagery with a spatial resolution of 250 metres taken every 1-2 days.
- Landsat satellite provides imagery with a 30 metre resolution (visible & NIR). Completes about 14 full orbits each day, and crosses every point on earth once every 16 days.

Through the development of UAV technology, it is possible to overcome these limitations for smaller scale EIA projects. By employing UAV technology, imagery can be captured with much higher resolution (<5 cm pixel), in suitable whether conditions, at a scale customised to a project and cost effectively.

Impact Assessment Case Study – Identification of Groundwater Dependent Ecosystems

Since the Millennium drought there has been an increased level of research into GDE. This has led to a greater understanding of how GDEs interact with, and their association with environmental processes. Subsequently, planning authorities and the community alike are requiring GDEs be considered in EIA studies where a project may have a consequential impact on vegetation, flora and fauna by altering surface water and groundwater processes.

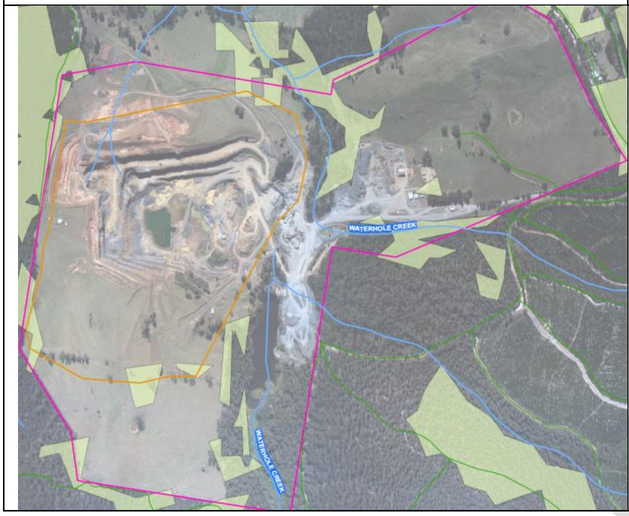
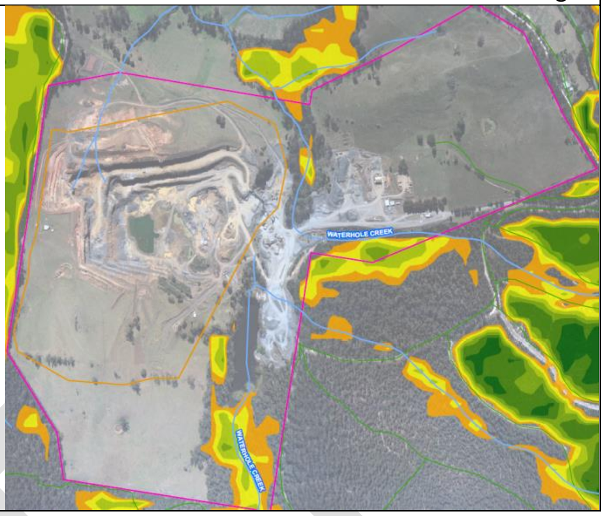
Groundwater Dependent Ecosystems are considered to be terrestrial or aquatic ecosystems that utilise groundwater resources. The utilisation of groundwater by a GDE may vary from continuous dependence, to reliance in dry parts of the year when surface water is not available, or indeed in dry years only (Eamus 2009). Eamus (2009) categorises GDE’s into two types; those that rely on surface water expression such as swamps, wetlands and rivers, and those that rely on subsurface access to groundwater within the rooting depth of vegetation.

The Australian government has invested resources into understanding the processes and national extent of GDEs via a mapping tool known as the GDE Atlas (BOM 2017). Similarly, several Australian State governments and indeed governments across the southern hemisphere have set about mapping likely areas of GDE. The Victorian State government has developed a GDE mapping package that draws on a range of existing environmental datasets and modelling including groundwater records, vegetation type modelling, digital elevation models (DEM), lithology and soil type (Dresel *et al.* 2010). Most importantly, the Victorian GDE model uses the NDVI model from MODIS and Landsat imagery to identify vegetation likely to be utilising groundwater. When combined with the aforementioned environmental datasets, this provides relatively accurate modelling of likely GDEs.

As part of an EIA study for a basalt quarry expansion project in south-eastern Victoria, Australia, AECOM was engaged to determine if GDEs would be negatively impacted by groundwater extraction requirements associated with a quarry expansion. AECOM utilised the Victorian government GDE modelling to determine the likelihood of GDE's presence within the proposed project area. Although the quarry expansion was located within the GDE model, due to the large pixel size of the model, it was considered that further investigation was needed to determine likelihood of GDE presence.

AECOM sought to replicate the process of the Victorian government GDE model by employing the NDVI model on Landsat 7 satellite imagery which has a reduced pixel size of 25 metres.

Monthly Landsat 7 imagery from January 2017 was utilised for the NDVI model. This was a known dry period in south-eastern Australia. Imagery was used from a known dry period as this was considered to be a representative sample of when GDE's would not have access to surface water, therefore more likely to utilise groundwater. Plate 1 below shows the project area with Victorian government GDE likelihood mapping and Plate 2 shows the project area with the NDVI model on Landsat 7 imagery from January 2017. Darker green areas in the drainage line show a higher likelihood of GDE presence due to a stronger chlorophyll reflectance signature. A comparison of the two images shows similarities in areas identified as containing GDE's, with the AECOM image showing a greater level of accuracy. It is interesting to note that coloured areas in the far left and right of the images show a native forest regenerating from a recent fire and a young Radiata Pine plantation respectively. These areas are showing a strong chlorophyll reflectance due to the productive growth rates of these forests types.

Plate 1 Victorian Government GDE likiehood model	Plate 2 AECOM NDVI model on 2017 Landsat 7 image
	

After the NDVI modelling was undertaken, a targeted field program was completed as a means of ground truthing modelled data. The field program recorded several features considered characteristic of GDEs. This included several areas of groundwater discharge, Damp Forest vegetation type and several fern species indicative of damp areas that may access groundwater resources such as Soft Tree-fern *Dicksonia antarctica,* Gristle Fern *Blechnum cartilagineum,* and Bristly Shield-fern *Lastreopsis hispida* (AECOM 2017). The adopted approach was considered appropriate due to being able to solely use Landsat 7 imagery which provides a higher level of accuracy as seen in a comparison between Plate 1 and Plate 2. Additionally, the range of chlorophyll reflectance was able to be detected via Landsat 7 imagery enabling areas to be targeted during field investigations that may contain a higher likelihood of containing a GDE.

Summary

Satellite based remote sensing has become an integral tool for environmental scientists to measure and model environmental patterns. In the past these monitoring methods have largely been limited to a regional and global scale. Advances in UAV and camera technology have led to an increased application of these tools for biodiversity conservation, precision agriculture and land management at a local and project based scale. An opportunity exists to utilise such technology for EIA studies of various scales.

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