USE OF REMOTE SENSING TECHNOLOGIES IN WEED MAPPING AND APPLICATION SYSTEMS

Species qualitative and quantitative analysis
WEED MAPPING AND APPLICATION SYSTEMS

Reliable, up to date information on weed abundance, distribution, and change over time is essential for all aspects of broadscale weed management. Such information is necessary to evaluate control strategies, prevent spread to clean areas, and to improve weed management.

Conventional weed mapping techniques are expensive, time consuming and are generally not repeated frequently enough to monitor important changes in infestations. They are also inefficient where the target weeds cover a wide geographic area.

Remote sensing offers a low cost, repeatable alternative for mapping and monitoring weed infestations over large areas, although with several limitations. For remote sensing to be successful, the target weeds must have distinct reflectance differences from background vegetation, soil and stubble. For detection by current multispectral sensors, these differences must be great enough to compensate for the broad spectral bands and the pixel size of the sensor. Detection may also be limited by the density of the weed infestation. "In order to successfully apply remote sensing technology to weed mapping, there must be some characteristic of the weed of interest that permits its spectral discrimination from other species with which it is associated. Such features as distinctive leaf shape, floral characteristics or phenological attributes need to be defined that allow the target weed to be distinguished from its associates at certain stages during its life cycle or under certain environmental conditions. In conjunction with this, consideration must be given to the spatial arrangements of weed patches. The spectral signal from a plant that grows in patches smaller than the spatial resolution of the remote sensing imagery may be significantly 'diluted' by the signal from the major land cover within a given pixel, thus reducing its ability to be detected." (Bulman 2002)

Despite these limitations, mapping of infestations is possible. In a recent study, up to 86% of Scotch thistle infestations in pasture were detected across a large geographic area, at an infestation density of down to 20% groundcover. Similarly, 72 – 82% of serrated tussock infestations were also detected, at an infestation level of down to 30 – 40% groundcover. (McGowen, 2000) Such studies indicate the potential of remote sensing for weed mapping over large areas. The reliability of remote sensing for weed mapping will improve as imagery from new high resolution sensors becomes available.

Recent studies utilizing current high resolution satellite imagery have demonstrated that it is possible to detect vegetation in arable fields with broad leafed weed patches larger than about 0.7m in diameter, about 25% of the Quickbird multi-spectral pixel area (2.44m) (Table 1). (Backes, M., Jacobi J. 2006) The direct implications suggest that the larger the patch size the more reliable this generation of imagery is in distinguishing between weed types in a mixed weed environment. Study results indicate detection accuracy was positively influenced by the density and the size of weed infestations.
The imagery resolution required to map a weed infestation is dependent on the smallest patch size that must be mapped. Specifically, the pixel size of the imagery should be at least one-fourth the area of the smallest patches that need to be mapped. This is because the placement of the pixel boundaries will not necessarily line up with the boundaries of the weed patches. Pixels covering part of a weed patch and part of an uninfected area will generally be identified as uninfested when the data are analyzed. This leads to missed patches (Figure 1).

![Table 1](http://www.digitalglobe.com/product/basic_imagery.shtml)

**Table 1**

<table>
<thead>
<tr>
<th>Spectral Characteristics</th>
<th>Panchromatic</th>
<th>Multispectral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black &amp; White</td>
<td>450 to 900-nm</td>
<td>450 to 520-nm</td>
</tr>
<tr>
<td>Blue</td>
<td>450 to 520-nm</td>
<td>520 to 600-nm</td>
</tr>
<tr>
<td>Green</td>
<td>520 to 600-nm</td>
<td>630 to 690-nm</td>
</tr>
<tr>
<td>Red</td>
<td>630 to 690-nm</td>
<td>750 to 900-nm</td>
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<tr>
<td>Near IR</td>
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| Pixel Resolution¹       | 61-cm to 72-cm (2 to 2.4-ft) | 2.44 to 2.88-m (8 to 9.4-ft) |
| Scene Dimensions        | 27,552 x 27,424 pixels        | 6,888 x 6,856 pixels         |
| Scene Size²             | 272-km² (nadir) to 435-km² (25° off-nadir) (105 to 168-mi²) |
|                         | 16.5-km² (nadir) to 20.8-km² (25° off-nadir) (10.3 to 12.9-mi²) |

**Figure 1**—(A) When weed patch size is the same as the pixel size, most patches will not be detected (grids represent imagery pixels). (B) If pixels are at least one-fourth the size of the patches, most patches will be properly identified. Red cells in the grids to the right indicate the pixels where weeds were identified in the imagery.
Data collection through remote sensing appears the most logical approach to acquiring appropriately distributed information over large areas in short time periods and on random sites far removed from easy ground access. The value of satellite and high-altitude sensors for landscape-level evaluations, such as plant community distribution, is well established.

Mapping invasive weeds using remote sensing requires matching sensor and platform requirements to the weed's biological traits. There are a wide variety of aircraft and satellite data available, which differ in spectral resolution (number of bands), spatial resolution (pixel size), temporal resolution (repeat frequency, if applicable), and cost (low cost to expensive). There are four major methods to detect invasive weed: photo interpretation, supervised image classification, unsupervised image classification, and feature analysis. Error assessment is a critical element of weed mapping, and requires detailed data collection and analysis. Determining the extent of noxious plant populations on rangelands by ground surveys is difficult because of the generally great expanse and inaccessibility of these areas. The value of remote sensing techniques for rangeland assessment is well established (Carneggie et al. 1983, Tueller 1989, Driscoll et al. 1997). Plant canopy reflectance measurements have been used to distinguish noxious brush and weed species from other rangeland plant species (Gausman 1985, Everitt et al. 2000).

Season is an important variable for detecting many plant species because their reflectance often varies at different times of the year and many species are distinguishable only when in a specific phenological stage. Other characteristics such as canopy architecture, vegetative density, and leaf pubescence are also important for detecting some species.

Previous research have demonstrated that wavelengths in the visible and the near-infrared regions of the spectrum exhibit great power in separating species (Vrindts & Baerdemaeker, 1997; Vrindts et al., 2002). Smith and Blackshaw (2003) suggested that, regardless of the input samples, wavelengths 700–730 nm were important for vegetation discrimination. These wavelengths fall within the region of spectrum known as the red-edge which is the region of rapid change in reflectance of chlorophyll in the near infrared range. Vegetation absorbs most of the light in the visible part of the spectrum but is strongly reflective at wavelengths greater than 700 nm. The change can be from 5% to 50% reflectance between 680 nm to 730 nm. This is an advantage to plants to avoid overheating during photosynthesis. The red-edge accounts for the brightness of foliage in infrared photography. It is used in remote sensing to monitor plant activity. (Horler et al. 1984) Recent interest in weed remote sensing has increased the need to use documented weed spectral libraries. Spectral library information can provide inputs to canopy radiation models and can help determine which sensors are able to detect a given weed species, by maximizing detection accuracy and minimizing cost of detection according to spatial, spectral, radiometric and temporal resolutions of each sensor Classification algorithms need to have a spectral reflectance pattern for all existing vegetation features and weed groups. Spectral reflectance patterns from the known weed locations on the images with the addition of handheld spectrometer readings are used for classifying each pixel.
Spatially Based Spraying System:
The design of spraying events and spray monitoring provides assistance to pilots and managers in assessing the quality and effectiveness of applications.

Once weed patches have been identified an integrated GIS/GPS mapping system and heads-up display assists the pilot in aerial spraying regimes. The system incorporates a moving map display that includes messaging and other information, such as a digital heading dial. This system is deployed via a tablet computer with a non-reflective LCD display incorporating screen technology for use in high light conditions. (Figure 2) The cockpit unit contains the GPS, power conditioning inverter, and a reserve battery. The moving map displays a pictorial representation of the surface below as well as all control prompts and flight navigation data. The software is driven from digital on screen buttons or can be controlled by remote buttons. The moving map display can assist navigation along defined blocks or defined routes through a pre-programmed file, providing the pilot with a clear and precise picture of his location relative to topographical features, hazards, block boundaries and flight lines. The display can also indicate to the pilot where to start and stop the runs, and warns him when he is entering no spray or avoidance zones. The system displays real time progress during application. An additional use of the system is the ability to review an accurate record of where the applicator flew (a graphically displayed, digital flight line). The system also captures application data when interfaced with a spray monitoring program and hardware that includes the exact location of the aircraft, nozzle activity and flow. Utilizing DGPS technology the spatial data is accurate to +/- 1 meter.

The final data can either be input into a GIS system for current and temporal analysis by managers as well as supports the generation of a variety of spray maps.
Surface terrain maps can be integrated into the heads-up display

Spray block maps prepared pre-flight
Literature Cited


Ian McGowen, Paul Frazier and Peter Orchard. Remote sensing for broadscale weed mapping – is it possible? NSW Agriculture


