Using Spectral Vegetation Indices to Differentiate Weeds and Mint in Remote Sensing Images

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Introduction

Remote sensing-based site-specific weed management has potential for simplifying weed detection, producing site specific herbicide maps, and decreasing weed control costs in peppermint and spearmint (“mint”). Mint is an ideal candidate for site-specific weed management as it has a low growth habit and patchy weed infestations. In 2004, we reported that highly accurate maps of mint crop health and weed infestations can be developed using supervised classification techniques; however, the accuracy of these techniques relies on extensive ground referencing. In order to make remote sensing a practical on-farm technology, our research is currently focusing on techniques to analyze remotely sensed images and convert them into weed (or pest) maps with a minimal amount of ground referencing.

Spectral vegetation indices have been shown to be useful in discriminating between different vegetation types but are not effective for all crops. Spectral vegetation indices (SVIs) are usually ratios of reflectance values at different wavelengths but may be other functions of reflectance (e.g. average reflectance over a range of wavelengths). If SVIs prove to be accurate in mint for differentiating between weeds and mint crop conditions, analysis of remote sensing images would not require extensive ground referencing. Such technique development would allow remote sensing-based site-specific weed management to become a practical, effective and economical on-farm technology.

The objective of this experiment was to evaluate the use of SVIs to differentiate between peppermint and problem weed species and their utility in analysis of remotely sensed images.

Materials and Methods

Greenhouse Reflectance Data

Hyperspectral reflectance data (511 evenly spaced bands from 296 to 1094 nm) were collected from small flats ($1m^2$) of mint and weeds using a GER1500 spectroradiometer. Flats included: ‘Black Mitcham’ peppermint (*Mentha piperita*), native spearmint (*M. spicata*), giant foxtail (*Setaria faberi*), white cockle (*Silene alba*), waterhemp (*Amaranthus tuberculatus*), a mixture of smooth pigweed (*A. hybridus*) and Powell amaranth (*A. powellii*), and a mixture of waterhemp, smooth pigweed and Powell amaranth. All measurements were replicated 9 times. Twenty three SVIs which had been shown to differentiate between vegetation types in other crops (Apan et al., 2003; Thenkabail et al., 2002) were calculated from reflectance data.

Hyperspectral Image Data

A hyperspectral image of a 14 ha peppermint field was acquired on September 10, 2004, using an RDACS - H3 aerial hyperspectral camera which collected 60 evenly spaced bands from 473 to 827nm. Pixel resolution was $0.7\ m^2$. Images were geometrically corrected and projected to geographic coordinates (latitude and longitude) using the WGS84 spheroid. Reflectance measurements of 13 calibration points were taken in the field using the GER1500 for use in calculating reflectance values from the image digital numbers (DNs) using the empirical line method (Smith and Milton, 1999). Natural field weed populations and variation in peppermint crop health were mapped using ArcPad 6.0.2 on a Dell Axim handheld computer equipped with a WAAS-enabled DGPS receiver. DN values were obtained for pixels located in weedy and weed-free patches. Border pixels were excluded. DN values were converted to reflectance and used to calculate the spectral vegetation indices found useful in the greenhouse experiment.

Results

Index Evaluation

Spectral response curves differed for monocultures of peppermint, spearmint, and weeds (Figure 1). Peppermint and spearmint had greater reflectance at wavelengths of 670 nm and above (near-infrared (NIR) region) as well as a steeper slope from 640 to 740 nm (the "red edge") followed in order by giant foxtail, white cockle, waterhemp alone, the mixture of waterhemp, Powell amaranth, and smooth pigweed, and the mixture of Powell amaranth and smooth pigweed. These separations in spectral response between crops and the various weed monocultures (both dicot and monocot) indicate that NIR reflectance was useful in distinguishing the mint crop from monoculture weed patches. Our results were consistent with previous studies showing differences in NIR reflectance between plant species with different leaf morphology (Apan, et al., 2003), and suggest this technique could be useful for site-specific herbicide application.

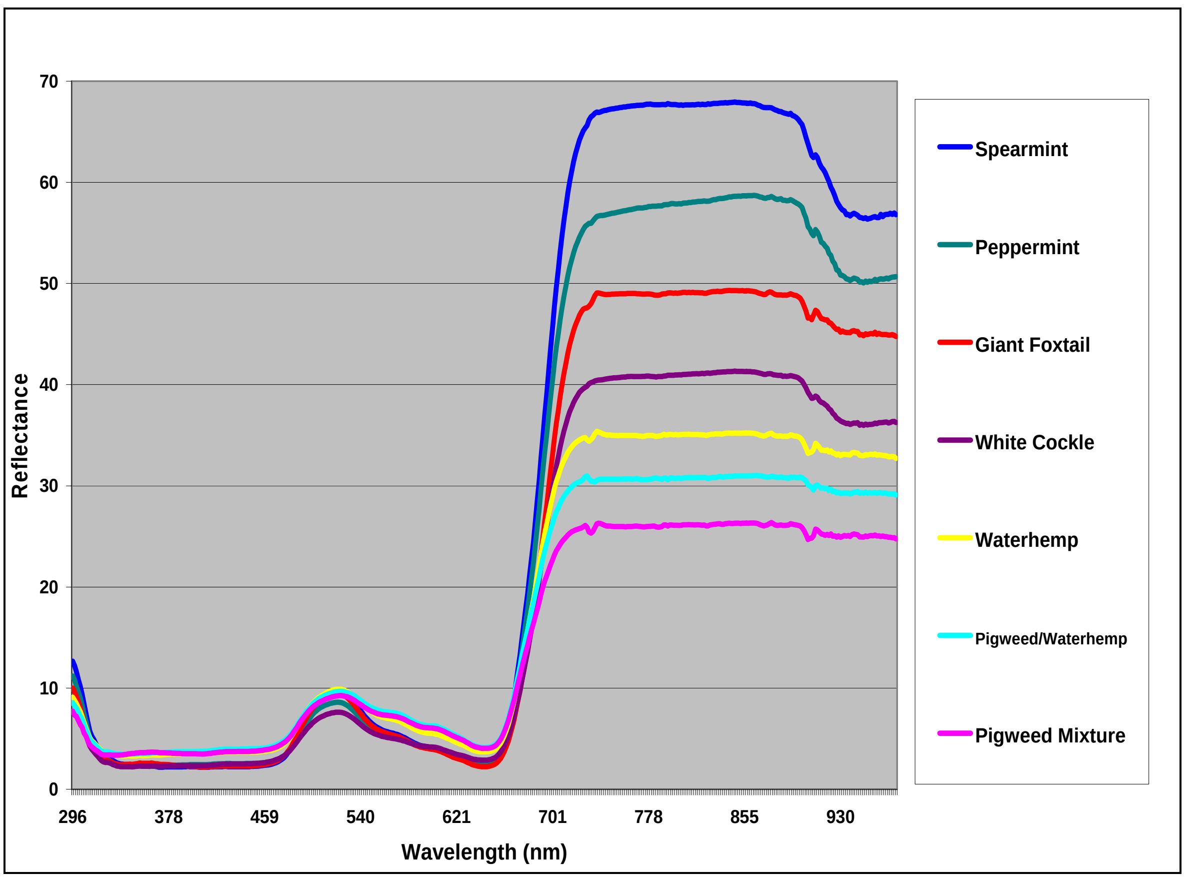

Figure 1. Spectral reflectance of peppermint, spearmint, and problem weed species.

Out of the 23 SVIs evaluated, five were able to consistently differentiate peppermint and spearmint from weeds: 3 simple wavelength ratios (SR) of 800/551, 750/551, or 695/420, an Average Reflectance (750 to 850 nm), and a Red Edge Slope (Table 1). These ratios all included wavelengths where differences in reflectance between mint and weeds were greatest (Figure 1).Only Average Reflectance (750 to 850 nm) and Red Edge Slope were able to separate all crop and weed species. These two induces appear to be the best SVIs for use in image analysis and were therefore further evaluated in field studies.

Table 1. SVI values for greenhouse-grown peppermint, spearmint, and problem weed species.

	SR 800/551	**SR 750/551**	**SR 695/420**	**Average Reflectance 750-840**	**Red Edge Slope**
Spearmint	**10.42a***	**10.36a**	**16.68a**	**67.68a**	**0.64a**
Peppermint	**9.75a**	**9.59b**	**13.39b**	**57.86b**	**0.54b**
Giant Foxtail	**7.80b**	**7.79c**	**11.62c**	**49.07c**	**0.47b**
White Cockle	**7.67b**	**7.61c**	**10.27d**	**40.98d**	**0.38d**
Waterhemp	**4.58c**	**4.57d**	**6.96e**	**35.04e**	**0.32e**
Waterhemp-Pigweed Mixture	**3.83d**	**3.82e**	**6.08f**	**30.76f**	**0.26f**
Pigweed Mixture	**3.37d**	**3.35e**	**5.57f**	**26.08g**	**0.22g**
Bare Soil	**1.83e**	**1.67f**	**2.07g**	**7.51h**	**0.02h**

<u>Hyperspectral Image Evaluation for Determining Field Conditions</u>

A hyperspectral image of a peppermint field for September 10 (Figure 2), showed weed and crop regrowth after crop harvest on July 22. Weed infestations were patchy and occurred where the mint crop was the weakest. Field scouting notes superimposed on the image show examples of locations where yellow nutsedge (*Cyperus esculentus*) (1), mixed Powell amaranth and smooth pigweed (2), dead crabgrass (*Digitaria sanguinalis*) (3) and weed-free peppermint (4) occurred. Differences in pixels of weed patches compared to healthy mint are obvious in the hyperspectral image. Spectral differences between weed free peppermint and weeds were used to locate weed patches in the hyperspectral image. Figure 3 shows actual peppermint and weed patches.

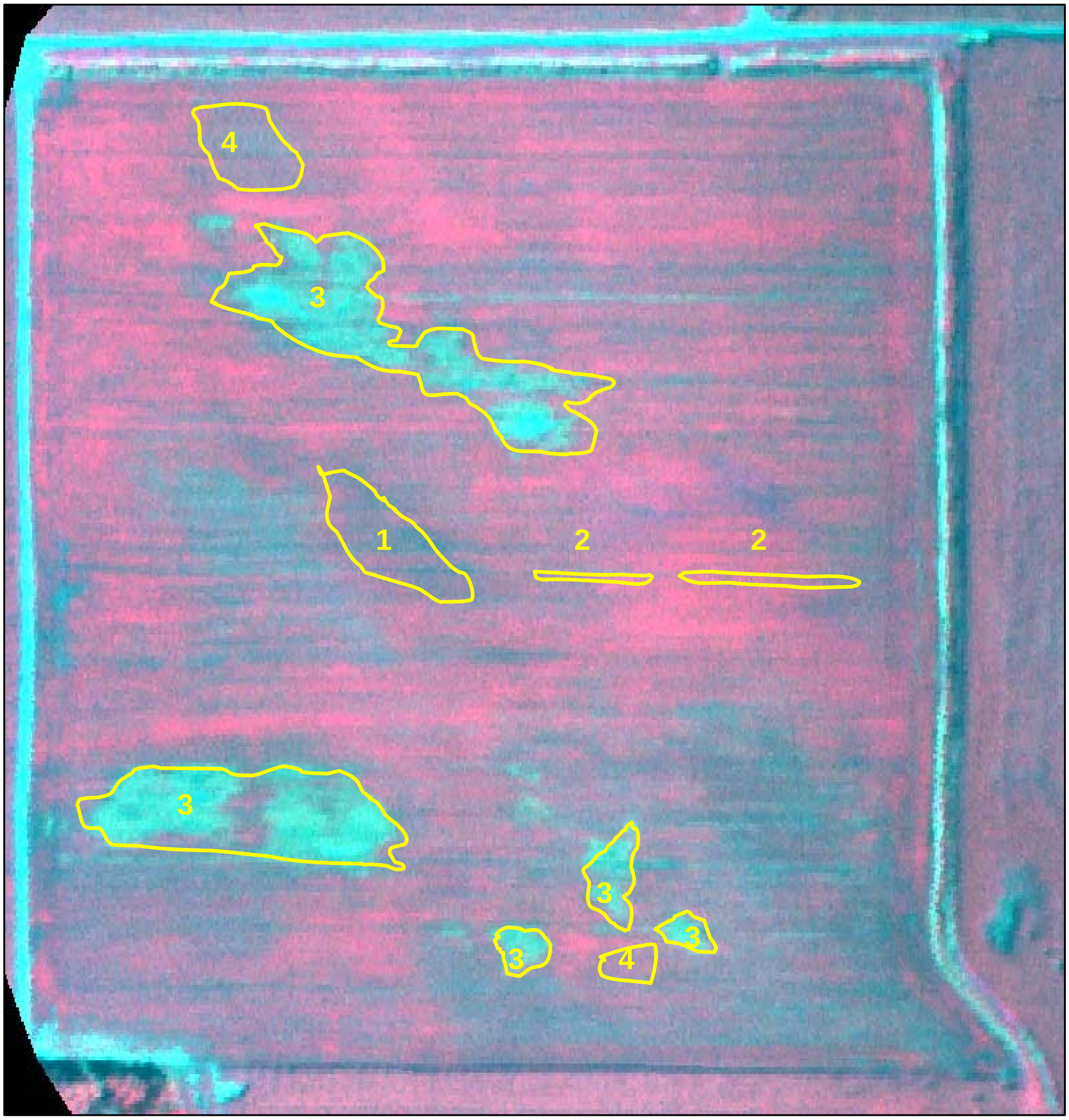

Figure 2. Hyperspectral Image of a Peppermint Field (Bands: 57, 27, 4).

Figure 3- Field conditions shown in hyperspectral image (A – weed free peppermint; B-Powell Amaranth; C-yellow nutsedge; D- dead crabgrass).

The SVIs useful in showing differences between mint and weed species in the greenhouse experiment (Table 1) were applied to reflectance data of the hyperspectral field image (Figure 2). Calculated reflectance values from weed-free mint, areas of *Amaranthus* spp., and yellow nutsedge were used to determine the SVI values (Table 2). SR 695/479 was substituted for SR 695/420 due to the smaller spectral range of the RDACS-H3 compared to the GER1500. SR 695/479, Red Edge Slope, and Average Reflectance (750 to 850 nm) differentiated between weeds and weed-free peppermint and identified weed patches within the field. Values for Average Reflectance (750 to 850 nm) and Red Edge Slope patterns were similar to those observed for greenhouse grown plants (Table 1). Differences in the actual SVI values in the greenhouse and field study are likely due to variation in morphology, leaf arrangement and nutritional status of plants grown under different environmental conditions that affect actual spectral reflectance.

Table 2. SVI values for natural field populations of peppermint and weeds.

	SR 800/551	SR 750/551	SR 695/479	Average Reflectance 750-850	Red Edge Slope
Weed free-Peppermint	16.03a*	10.36a	1.77b	46.27b	0.26b
Pigweed Mix	15.80a	10.34a	2.32a	50.21a	0.29a
Yellow nutsedge	10.70b	6.45b	0.30c	35.45c	0.17c

Conclusions

- SVIs were useful for differentiating between mint and weeds grown under greenhouse or field conditions.
- SR 695/479, Average Reflectance (750 to 850nm), and Red Edge Slope accurately predicted specifics regarding weed species composition and location in a field image.
- SVIs obtained from greenhouse grown plants can be used to analyze field hyperspectral imagery.

SVIs represent a promising development towards automating the analysis of remote sensing images and the development of weed maps. Future research on this project will confirm the spectral response values using field grown plants and develop more indices specifically for differentiation between mint and weeds.

Literature Cited

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