Site-Specific Management Guidelines

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Using Remote Sensing to Develop Weed Management Zones in Soybeans

Summary

Crop scouting should provide accurate, timely, and cost effective information about diseases, insects, nutrient deficiencies, and weeds in production fields. Approaches for weed scouting include examining edges of fields or driving across fields in an X or W pattern to determine weed species present. Often weeds or weed species are spatially aggregated and using traditional approaches usually will not produce enough information for site-specific weed management recommendations. Remote sensing can be used to guide ground-scouting activities and identify the extent of weed patches. Ground-truthed remote sensing information can be used to develop effective weed management strategies and monitor weed management successes and failures. Four critical decisions that should be considered to integrate remote sensed data into agronomic management include:

- Feasibility of using remote sensing as a field-scouting tool;
- Reflectance bands used to distinguish weed-infested and weed-free areas in soybeans;
- When to collect the remote sensed data; and
- Spatial resolution needed for weed patch detection.

This guide provides information to help answer these questions.

Introduction

Weed scouting is a key component of integrated weed management programs (Clay and Johnson, 2002). Scouting is complicated by the fact that weed densities and species are highly aggregated (or patchy) in most fields (Cardina et al., 1996; Clay et al., 1999; Johnson et al., 1995). Patchiness can be caused by field variability in drainage, topography, soil type, and microclimate (Radosevich et al., 1997). Due to patchiness of field infestations, uniformly treating entire fields can result in unsatisfactory weed control or unnecessary use of herbicides. Remote sensing may be a technique that will improve weed scouting and result in better management decisions. Discussions of the basics of remote sensing are beyond the scope of this guideline, but are available in Dalsted and Queen (1999), Johannsen et al. (1999), Thankabail et al. (2002), and Dalsted et al. (2003). The focus of this guideline is to provide guidance on how remote sensing can be used for weed detection.

Remote sensing research has shown that different targets have different reflectance characteristics. In general:

- Bare soil reflects less incoming radiation than plants in the near-infrared (NIR) band (Dalsted and Queen 1999), whereas fresh residue reflects high amounts of energy in all bands.
- Healthy plants with greater canopy cover reflect more radiation in the NIR band than plants under stress from factors such as water, insects, diseases, or fertility problems.
- Different plants have different reflectance characteristics that are influenced by plant characteristics such as variety, maturity, or stress. Therefore, characterizing plant species based on reflectance characteristics is difficult.
- If the question is changed from "Can remote sensing be used to identify weed species in a field?" to "Does this field contain weeds?" it may be possible to use remote sensing and directed ground scouting to develop treatment maps.

Feasibility of Using Remote Sensing for Weed Scouting

When evaluating the feasibility of using remote sensing as a scouting tool, understanding that differences occur between what we see and what a remote sensing instrument records are important. Our eyes act as our remote sensors. We can easily identify weed-free and weedy areas in a soybean field and distinguish between different weed species based on leaf shapes and sizes (**Figure 1a**). When a remote sensing instrument collects reflectance at the field scale, reflectance values from individual features are averaged over the entire pixel area. In remote sensing, resolution of an image is explained in terms of pixels. Resolution of a remote sensor ranges from low to high. For high resolution, an image is expressed in many small

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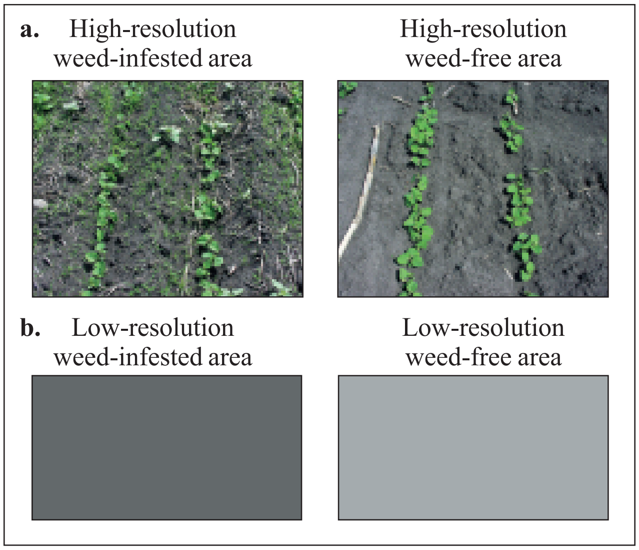

Figure 1. A comparison between weed-infested and weed-free areas in a soybean field using high and low resolution images. The high-resolution images (a) provide images that are seen with our eyes. The gray images (b) show how these areas may appear when taken with a low-resolution remote sensor.

pixels, while low-resolution images are composed of fewer, large pixels. The low-resolution image is seen as a single color (**Figure 1b**) while in the high-resolution digital image, individual plants can be seen (**Figure 1a**).

In a remote sensed image, the average reflectance value from the weed-infested area (**Figure 1b**) usually has a high reflectance value (shown as dark gray) and the weed-free area usually has a lower reflectance value (shown as light gray). These differences are due to the amount of canopy cover...the weedy area having greater canopy cover than the weed-free area.

Reflectance Bands Used to Distinguish Weed and Non-Weed Field Areas

Research has been conducted to determine which reflectance bands are most useful for detecting weeds. The visible and near infrared spectrum is typically split into four band areas: blue, green, red, and near infrared (NIR). The NIR reflectance has been found to be the most useful in distinguishing between weed-infested and weed-free areas. NIR reflectance can be combined with other bands such as red or green to produce a variety of vegetative indexes such as Normalized Difference Vegetative Index (NDVI) or Green Normalized Difference Vegetative Index (GNDVI) (Dalsted and Queen, 1999). Research suggests that if only one band is collected, then the NIR should be selected. If additional bands can be collected, then the red, green, and panchromatic bands would be useful to evaluate biomass production and calculate vegetative indices.

Timing of Data Collection

Early season. It is difficult to use remote sensing to determine weeds early in the season when they are small because soil dominates the reflectance characteristics of most pixels. As the season progresses, weedy areas can be identified (**Figure 2**). Weeds could be detected between 20% canopy cover (V3 soybean growth stage) through 85% canopy cover. After full canopy cover, weedy areas could not be clearly distinguished in the images.

The higher reflectance values from weed-infested areas are due to the higher canopy cover in weed-infested areas, with plants growing both within and between soybean rows (**Figure 1**). Reflectance values from weed-free areas, where soybean plants were still relatively small, were low and very similar to bare soil until the plant canopy dominated the pixel.

Additional studies were conducted in 2002 [soybeans grown in low residue (15 to 20%) and high residue (corn residue of 80%)] and 2003 (corn). The magnitude of the differences and times when differences could be distinguished were similar to those reported above, although results from the high residue plots were slightly different. Residue areas had higher reflectance values than bare soil. Differences between weed-free and weedy areas were first noted on June 17 (soybean stage V-3) when minimal residue was present, whereas in high residue plots differences were first noted on June 27 (soybean stage V-4).

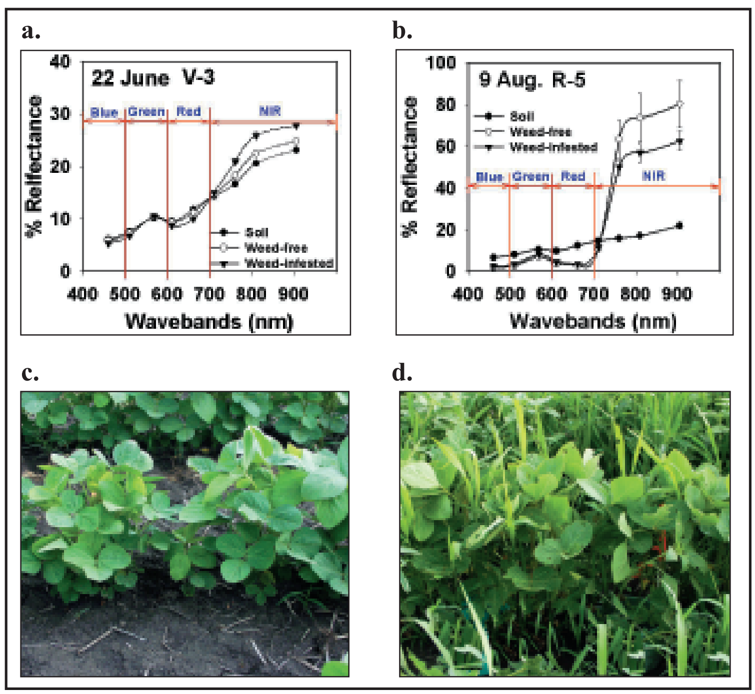

Figure 2. The charts (a and b) show present reflectance from weed-free and weedy areas in a soybean field. The pictures show (c) a weed-free area where soybeans were at V4 and canopy cover was about 30%, and (d) a weed-infested area in the soybean field. Soybean canopy cover was about 30% and total canopy cover was close to 90%. The difference in reflectance shown in (a) and (b) between weed-free and weed-infested areas was due to more green vegetation covering the soil.

The timeframe of mid June through July for collecting remote sensing imagery is practical because corrective treatments can be applied in a timely manner before the crop gets too tall. One problem with this timeframe is cloud cover. Remote sensing cannot be obtained when the sky is cloudy. Satellites may pass over your area at best once or twice a week, or as infrequently as once every 2 weeks. Therefore, finding a sunny day to collect the imagery is sometimes a challenge. If you intend to use satellite imagery during this time, a back-up plan of using remote sensing collected by an airplane may be needed. Scheduling an airplane to collect imagery is more flexible, making it easier to take the picture when the sun is shining.

Late season. Late in the season, when the crop reaches maturity and begins to dry down, there may be another opportunity to distinguish weeds from crop areas, especially if weeds remain green (**Figure 3**). Again the NIR wavelengths were a good choice to see differences between weed-free and weed-infested areas. Canada thistle patches, which were circular in shape and had high reflectance values in the NIR spectral range, were clearly identifiable at the summit and backslope positions of the field (Broulik et al., 1997). These patches ranged in size from about 1,000 to 17,000 ft^2 with the highest density of about 10 plants/ft^2 in the center of a patch. In the toeslope positions of the field, high densities of common ragweed were present. Additional scouting, using this image as a field map, revealed areas containing quackgrass (*Elytrigia repens*) and annual grasses…foxtails (*Setaria sp.*) and barnyardgrass (*Echinochloa crus-galli*)…that had not been controlled. Since this image is georegistered, it can be used as a spray guide for perennial weed control in the fall and a scouting tool in the spring.

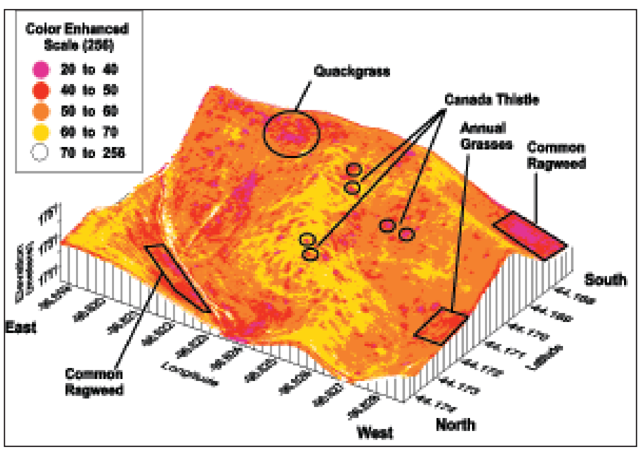

Figure 3. Aerial NIR image (11 ft^2 pixel resolution) of a 160-acre soybean field in Moody County, South Dakota, taken in early October just prior to harvest.

Pixel Size

Another consideration when obtaining field images is the size of the pixel that will present the "best" information for a field. This will be determined by your preference and the minimum patch size you want to observe. As pixel size increases, the resolution decreases. Dalsted and Queen (1999) discuss the differences and resolution observed in pixel size ranging from 11 to 323 ft^2. Dalsted et al. (2003) addressed the different pixel resolutions available, costs and repeat times for different satellite sensors. They also showed that if the weed patch was very large, such as leafy spurge infestations in range and pasture, Landsat (323 ft^2 pixel resolution) could be used to identify weed patches. However, in most crop production settings, weed patches will be much smaller and higher resolution will be needed. In **Figure 3**, the resolution of the image is 11 ft^2 (taken from an aerial platform) and Canada thistle patches as small as 22 ft^2 were observed. The relationship of pixel size to infestation area is critical because it impacts the ability to observe the problem, and determines 1) the data source (Landsat, IKONOS, aerial platform); 2) the data processing requirements; and 3) the cost of the product.

Developing Treatment Maps

This guideline presents suggestions for using remote sensing as a scouting tool. Follow-up with ground scouting should be done for confirmation of weed species and locations. High reflectance in a field does not always indicate weed-infestations. Poor crop growth could be due to a wide variety of conditions, including disease, hail, pesticide spray drift, wind damage, nutrient deficiencies, insects, or saline soil areas. These areas will have low reflectance, making normal crop growth appear to have a high reflectance. We recommend that remote sensing be used as a directed scouting tool to help identify both the problem and its extent. Once the factor(s) responsible for the change in reflectance characteristics is identified, then the remote sensed image can be used as a tool to assist in developing a treatment map.

Conclusions

Feasibility of using remote sensing as a weed-scouting tool. Scouting for weeds is an integral part of integrated pest management strategies and site-specific management. Reflectance data collected by remote sensing techniques can be used to augment ground based scouting when taken at appropriate times and resolutions for the problem. Limitations of the imagery must be realized. Weed, soil, and crop reflectance will be averaged into one number for an area. This area will depend on the pixel resolution of the image. The advantage of using remote sensing as a weed-scouting tool is that a picture of the entire field can be observed in a single image.

Other factors to consider when using remote sensing to scout for weeds include (1) cloud cover and (2) importance of ground-truthing the image. Satellite imagery cannot be collected under cloud cover. Also, when an anomalous area in an image suggests weeds are present, the area must be checked to confirm that the area actually contains weeds.

Reflectance bands used to distinguish weed and non-weed field areas. Weed patches could be detected in images taken when soybean canopy closure was from 20 to 85%. Areas with weed patches had higher reflectance in the NIR spectral range because vegetative cover was greater than normally expected. Research suggests that if only one band can be selected, the NIR band is the first choice to distinguish weed areas in fields. Other bands that have proven useful for estimating biomass, yields, and other crop factors include green, red, and panchromatic.

When to collect the imagery. Early season…the best time to collect imagery in soybeans is between 20 to 85% canopy closure. After canopy closure, it is difficult to identify weedy areas in soybean fields. Spring and early summer images may be difficult to obtain due to cloud cover. Satellites may pass over the field once a week or once every two weeks. Therefore, if satellites are used to collect the imagery, a backup plan such as collecting imagery from an airplane should be available.

In late season, an optimal time window for detecting perennial weeds starts in the fall when crop senescence starts and ends at a killing frost. This approach may have limited utility if the season has been dry or if the weeds senesce at the same time as the crop. Imagery obtained in the fall can be used to plan spring, preharvest, or postharvest herbicide applications depending on the weed species, density, or extent of infested area.

Pixel size. Our preference for pixel size is to use the highest resolution (smallest pixel size) available that will still give a field-wide view. The relationship among pixel size, cost, and the requirements of the problem must be considered in selecting the appropriate data source. Not all problems require the same resolution.

Developing treatment maps. The images may be used to develop treatment maps. The accuracy of the image should be assessed using ground scouting and weed species should be noted. This step is important because this technique will not identify weed species and high residue areas could be confused with weed patches. It is also important to assess the success of the weed management strategy after treatment so that follow-up treatments can be applied if necessary.

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References

Broulik, B.L., G.J. Lems, S.A. Clay, D.E. Clay, and M.M. Ellsbury. 1997. Analysis of spatial distribution of Canada thistle (*Cirsium arvense*) in no-till soybean (*Glycine max*). Proc. South Dakota Acad. Sci. 76:159-169.

Cardina, J., D. Sparrow, and E.L. McCoy. 1996. Spatial relationships between seedbank and seedling populations of common lambsquarters (*Chenopodium album*) and annual grasses. Weed Sci. 44:298-308.

Clay, S.A., G.J. Lems, D.E. Clay, F. Forcella, M.M. Ellsbury, and C.G. Carlson. 1999. Sampling weed spatial variability on a fieldwide scale. Weed Sci. 47:674-681.

Clay, S.A. and G.A. Johnson. 2002. Scouting for weeds. Crop Management. Doi:10.1094/cm-2002-1206-01-MA Published Dec. 2002.

Dalsted, K., D.E. Clay, S.A. Clay, C. Reese, and J. Chang. 2003. Selecting the appropriate remote sensing product for precision farming. Site-Specific Management Guideline #40. Potash & Phosphate Institute. Online at: www.ppi-far.org/SSMG.

Dalsted, K. and L. Queen. 1999. Interpreting remote sensing data. Site-Specific Management Guideline #26. Potash & Phosphate Institute. Online at: www.ppi-far.org/SSMG.

Johannsen, C.J., P.G. Carter, D.K. Morris, B. Erickson, and K. Ross. 1999. Potential applications of remote sensing. Site-Specific Management Guideline #22. Potash & Phosphate Institute. Online at www.ppi-far.org/SSMG.

Johnson, G.A., D.A. Moretnsen, and A. Martin. 1995. A simulation of herbicide use based on weed spatial distribution. Weed Res. 35:197-205.

Radosevich, S., J. Holt, and C. Ghersa. 1997. Principles of weed ecology. p. 43-65. *In* Weed Ecology. Implications for Weed Management. 589 p. John Wiley & Sons. New York.

Thankabail, P.S., R.B. Smith, and E. DePauw. 2002. Evaluation of narrowband and broadband vegetation indices for determining optimal hyperspectral wavebands for agricultural crop characterization.

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