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FARM LEVEL SPATIALLY-VARIABLE INSECTICIDE APPLICATIONS BASED ON REMOTELY SENSED IMAGERY

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Abstract

This is a continuation of an experiment that began in 1999, and was further explored in 2000. It consisted of the use of remotely sensed imagery to identify habitat suitable for the tarnished plant bug *Lygus lineolaris*. Remotely-sensed imagery maps areas of vibrant crop growth, facilitating on-the-ground scouting efforts to determine which areas of the field (or fields) may need to be treated by pesticides to prevent yield loss. The imagery may also provide a template for the generation of site-specific insecticide prescriptions (for example Bidrin, $6.80/acre). The 2001 Spatially Variable Insecticide (SVI) experiment at Perthshire Farms encompassed nearly 1000 acres. Remotely sensed multispectral imagery was collected every 7 to 10 days over the study site and was used to direct insect sampling. There were a total of 15 SVI applications during the growing season. Analysis of the yield data indicated no significant difference between spatially variable and blanket insecticide applications. Use of SVI technologies reduced insecticide usage and application costs by 44% and 33%, respectively.

Introduction

The tarnished plant bug is a detrimental pest of cotton and research shows the insect is attracted to fast-growing, vibrant cotton (Willers et al., 1999b). Additionaly, Willers et al. (1999a) demonstrated that plant bug densities differed by crop growth stage and with the use of remotely sensed imagery, could rapidly distinguish crop growth patterns throughout the field. Preliminary results indicate the potential for a savings of 40% in insecticide costs compared to traditional blanket application (Dupont et al., 2000; Seal, 1999). Extensive scouting data are available to suggest that spatially variable applications (including variations in the rate) were as effective in controlling the tarnished plant bug as broadcast applications (Spectral Visions, 2000). The results of the 1999 SVI experiment at Perthshire Farms indicated that cotton yields from fields managed in a spatially variable manner were statistically the same as those in fields managed exclusively with broadcast applications. In 2000, we expanded this research, in terms of sample points and acreage at Perthshire Farms. Work also began on a second SVI project at Hardwick Farms on the west bank of the Mississippi river, near Newellton, Louisiana. Although designed slightly different, the objectives of the second experiment were similar to those addressed at Perthshire. By utilizing these two experiments, the research team hoped to demonstrate the effectiveness of the SVI concept in two different farm-management environments.

The 2000 experiments at Perthshire Farms were designed to test the effectiveness of remote-sensing-based spatially variable insecticide to increase profits to the producer in terms of the following criteria; (1) cost savings, (2) effectiveness in eliminating plant bugs, and (3) ability to maintain acceptable yield levels compared to traditional blanket application of insecticide (Spectral Visions, 2000). It consisted of over 2000 acres of semi-contiguous fields ranging from 10 to 200 acres. Before planting, fields were designated to be SVI or conventional (blanket sprayed), resulting in 10 pairs of experimental fields. As with the 1999 results, we realized 35% – 40% savings in amount of insecticide applied, while also maintaining yield when compared to the conventionally sprayed fields.

The economic analysis suggested that the SVI method was cost effective and the average chemical reduction realized by utilizing SVI technologies was 34%. After integrating the application costs, data collection costs and prescription management costs, the cost of the SVI method as compared to the conventional method was reduced by 22%. This economic analysis demonstrated that using SVI technology for application of Bidrin to treat plant bug infestations instead of traditional broadcast methods reduced the cost of insecticide applications to the cotton producer (Spectral Visions, 2000).

For the 2001 project, the research team further explored the utility of Spatially Variable Insecticide (SVI) applications not only for the plant bug, but also for the feasibility of mapping other damaging cotton insects (White Flies, Aphids, spider mites, thrips, Tobacco Budworms, etc.) through crop growth patterns. This approach comes at the request of the many researchers, growers, and professional crop scouts that believed the experimental design from 2000 was too stringent, only attempting to control the plant bug, when in fact the entire insect complex should be studied. This was discussed at a research team meeting last November at Hardwick Farms near Newellton, LA.

Few researchers have utilized remote sensing to the extent envisioned by the Ag20/20 program. Fitzgerald et al. (1999) reported promising results derived from bit-error filtering on the near infrared band of multispectral imagery for the detection of spider mite damage. Work done by Gat et al. (1999) utilized hyperspectral imagery for the detection of insect infestations in cotton grown in the western United States. Another study by Summy, et al (1998) used color infrared photography to detect undestroyed cotton in support of a boll weevil eradication program.

One example of an applied remote sensing cotton insect project is the boll weevil eradication GIS that uses satellite imagery (Smith and Wiygul, 1997). Jim Johnson of ITD-Spectral Visions developed a similar prototype for boll weevil eradication in Oklahoma in 1998. Remote sensing in entomology was reviewed by Riley (1989), who discussed a wide range of attempts at insect mapping through aerial photos, radar, airborne and satellite imagery, and other data, including research of direct observation of flights of moths, grasshoppers, locusts, and other phenomena. A greater emphasis was placed on inference techniques, that is, detecting the effects or habitat of certain insects to infer their presence. Remote sensing projects for agricultural insect management at the time (1989) included mention of corn leaf aphids, milkweed as an indicator of monarch butterfly presence, and post-harvest standing cotton plants as an indicator of boll weevil over-wintering sites.

In addition, there are a number of research papers that approach site-specific management techniques for insect control, but do not utilize remote sensing. Parker, et al (1999), for example, evaluated insect management strategies through the use of yield-monitor data but not imagery data. In summary, a review of the literature and the experience gained from past SVI research conducted at Perthshire and Hardwick Farms reveals an opportunity to continue to do groundbreaking applied experimentation that may benefit Southern cotton producers and the remote sensing industry.

Objectives

The goal of the 2001 SVI research at Perthshire Farms was to continue building upon the experiences and knowledge gained from the 1999 and 2000 Spatially-Variable Insecticide research conducted at Perthshire and Hardwick Farms. The 2001 experiments are designed to test the effectiveness of remote-sensing-based spatially variable insecticide to increase profits to the producer in terms of the following criteria; (1) effectiveness in eliminating the insect populations which adversely affect the cotton crop, (2) maintaining yield of standard practice, and (3) cost savings to the producer. These criteria will determine successful execution of this experiment.

Materials and Methods

The experiment was conducted at Perthshire Farms near Gunnison, MS in the floodplain of the Mississippi River. The alluvial soils of the region are noted for their fertility and high yield potential. A series of semi-contiguous fields totaling 970 acres comprised the 2001 experiment (Figure 1).

The 2001 SVI experiment utilized a completely randomized design (CRD) replicated nine times. The experimental units were 18 fields ranging from 8 to 200 acres. Treatments (blanket or SVI) were assigned to the fields in a randomized manner. In an effort to concentrate resources, contain costs, and facilitate data collection, the scale of the experiment was about 1000 acres smaller than the 2000 SVI experiment.

This research incorporated the entire insect population that adversely affects cotton production at Perthshire Farms during the 2001 growing season, given that the insects are controllable with conventional spray applicators. We will rely on the expertise of the USDA and Perthshire Farms entomologists involved with this research to determine what insects migrate to the most vigorously growing areas of the crop (i.e. those insects that behave similarly to the tarnished plant bug), as well as those that tend to migrate to the least-vigorously growing areas of the crop. Insecticide application prescriptions will be tailored according to the behavior of the specific insect to be sprayed.

Data Acquisition

Data collection began in early June and continued throughout the growing season until insecticide application was no longer necessary (early- to mid-August). Multispectral imagery was acquired by ITD over the study area every 7-10 days (weather permitting) and processed according to the procedures outlined below.

The ITD RDACS/Model II (Mao and Kettler, 1985) airborne camera was used to collect multispectral imagery that consisted of three bands (840nm, 695nm, 540nm, +-5 nm) with a 2-meter resolution. The 1320 x 1024 pixel array captures a footprint of 2640m x 2048m on the ground (1350 acres). Space Imaging IKONOS data was also collected during the growing season. Because the IKONOS data sets were not delivered in a timely manner, the IKONOS data was not used in this study. From data acquisition to scout file generation, the turn-around time needed for successful implementation of this research was two days.

To calibrate the imagery, radiometric measurements were obtained on six features using an ASD FieldSpec Pro spectroradiometer (Analytical Spectral Devices, Inc., Boulder, CO). Each of the features exhibited varying levels of reflectance. To ensure the radiometric data was collected from the same location every time, each feature was georeferenced. Field spectroradiometer data of pseudo-invariant features was collected twice during the growing season (16 Apr. 2001 and 16 Aug. 2001).

Insect sampling data was collected using a stratified sampling strategy. Sample sites were distributed according to strata defined by the NDVI patterns in the multispectral imagery. Field scouts navigated to each of the sample sites using Compaq iPAQ hand-held computers collected insect samples using the drop-cloth method and/or sweep net methods. The iPAQs allowed the field scouts to reference their location in the field to a point in the digital scout map and instantaneously record data (i.e., insect counts, physical plant measurements, etc.) for that point.

After the fields were scouted, the scout files were copied from the iPAQ to the hard drive of the PC at Perthshire Farms. *i*Crop Client was then used to display the GoTo files and then send them to ITD via email or FTP. If insect levels met or exceeded the allowable threshold, the grower was notified and the *i*Crop Client software was used to request SVI prescriptions for the field or fields requiring treatment. The settings in the prescription request table were then sent to ITD at Stennis via email or FTP.

The *i*Crop software monitors the email or FTP site on a regular basis and when a prescription request table is received, prescription shapefiles and controller files are generated. The output files are zipped and sent back to the farm via email. With the assistance of ITD's field intern, the Perthshire Farms staff, and/or the research team, the SVI prescription(s) were loaded on the Case-IH Patriot ground-based sprayer and applied to the appropriate field(s) (Figure 2). As-applied data generated by the controller was collected after the SVI application and later delivered to ITD.

After the specified re-entry interval following the insecticide application, post-spray insect counts were collected in a manner similar to those collected before the insecticide application. Upon completion of scouting, the data were sent back to ITD via email or FTP. The entire process was repeated several times throughout the critical part of the growing season (June through August). Insecticide applications to control plant bugs ceased when the crop reached physiological maturity.

Image Pre-Processing Procedures

After image acquisition, an 8-mm tape containing the imagery is delivered to ITD at Stennis. The data are extracted onto disk and an automated script is run that extracts the second band of each frame. This band is exported to TIF format and stored as a gray-scale image. Using these images, a "Field-to-Frame" list is created to pair each of the study fields with the frames that contain them. This inspection is also used to determine the quality of the data. In some instances, one or more frames may not be usable because of cloud coverage or other sensor contamination. If a frame was unusable, it may be possible substitute an overlapping frame or a frame from another flight line. If no frame was of acceptable quality for a given field, the field is excluded from the Field-to-Frame list and thus from the analysis.

Next, the data were band-to-band registered. This process corrects for the small offsets of geographic features that occur between bands. A representative frame that has identifiable control points is selected and is broken into its four bands. The second band is used as the reference band. Control points (i.e., road intersections, buildings, etc.) between the first and second band are selected by the image analyst. These points are used to generate equations that will shift the first band to match the location of the control point in the second band. Essentially, the first band is snapped onto the second band such that common features share the same row and column address in both bands. The process is repeated with bands two and three as well as bands two and four. The process not only creates output files that may be stacked together to provide one 4-band image set, but also provides the equations that are used to perform the transformation. Since the band misregistration is common to all frames flown on the mission, the equations can be applied to the entire data set.

Once the frames were band-to-band registered, the georectification process was performed on the frames that contained the research fields. The image analyst selects points between the raw frames and the reference image (in this case, USGS Digital Othro-Photo Quarter Quads were used) of the research area. Nearest neighbor resampling was used for both the band-to-band and georectification processes. Each image was georectified to UTM coordinates (WGS84, zone 15 north).

After georectification, the imagery was calibrated using the empirical line method (Smith and Milton, 1999). This process converts the raw digital numbers to percent reflectance using the radiometer reflectance measurements collected at the pseudo-invariant features.

To simulate commercially available satellite imagery, the imagery is then resampled to a spatial resolution of 4 meters. Finally, the resampled imagery is masked to convert the area surrounding the research field to a background value. The final result of the masking process was a single image for each research field.

Image Processing Procedures

Upon completion of the image pre-processing, scout files (Figures 3 and 4) were generated and sent via email to Perthshire Farms. The scout files included an ArcPad project and the following files:

- Season-adjusted NDVI image. The classes are fixed for the season and fields can be compared throughout the season and with each other. The NDVI map used at Perthshire Farms consisted of 12 classes.
- NDVI Change Image. This delineates positive and negative vegetation changes from flight-to-flight. For this product, the raw NDVI of the specified date is subtracted from the current date NDVI. The difference map is divided into 10 fixed classes, with classes 1-4 representing negative change (four being slight; one being severe) and classes 5-10 representing positive change (classes approaching 10 indicate greater change).
- MaxView NDVI Image. Originally this was a 10-class equal area classification using global statistics. This was not deemed useful and a 5-class equal area image based on the field statistics for the date of imagery was tested. The 5-class did a good job of enhancing the within field differences and matched the hardcopy composite images.
- Hardcopy Maps. The hardcopy maps were created as JPEG images and display the multispectral image as well as the selected MaxView NDVI Image for each field.
- Prescription Request Table. This table allows the user to create spatially-variable prescriptions based on the NDVI images described above. All parameters needed to create a prescription are in the columns of this table. Some of the columns are preset (crop, application type, etc.); the remaining parameters will be set in the field. The prescription may be based on the season-adjusted NDVI, the change map, or the MaxView map. Chemical rates are set for each of the NDVI classes in the chosen index.
- Scouting GoTo Points. At Perthshire Farms, a stratified sampling strategy was used to generate the GoTo points. It used the season-adjusted image for the treatments (blanket and SVI). For both the pre- and post-spray insect samples, five points were randomly selected from each NDVI class. Insect names and counts were determined for each sample point.

Yield Data

Harvest of the study area took place at the end of September and first part of October. Cotton yield measurements were obtained using cotton pickers equipped with an Ag Leader PF3000 Pro (Ag Leader Technology, Ames, IA) commercial yield sensing system and DGPS receiver. Data were collected at 2-s intervals and written to a PCMCIA card located on the yield monitor. Yield monitor calibration was accomplished using a boll buggy equipped with an electronic scale. Randomly selected loads were weighed and compared with the yield monitor load weight. If necessary, correction factors were then applied to the yield monitor. Overall, the error was less than ±5%, with some individual loads below ±1%.

After harvest, data were downloaded from the PCMCIA cards and exported to comma-delimited ASCII files for further processing. First, all the data were merged into one source file. From the source file, the yield data for each of the 18 study fields was extracted and converted to an ESRI shapefile. Each of the shapefiles was edited to remove points logged when the picker had stopped and/or momentarily reversed its direction of travel (i.e., due to plugging). After editing was complete, the shapefile was saved and exported as a comma-delimited ASCII file.

Next, the yield data was processed with Microsoft Visual Basic (Microsoft Corporation, Redmond, Washington) using algorithms similar to those described by Birrell et al. (1996). Observations with yields below 15 lbs/acre and above 12000 lbs/acre were removed as well as observations collected when the picker was traveling at speeds less than 0.5 miles/hour. At the same time, geographic coordinates (longitude, latitude) were converted to Universal Transverse Mercator (UTM) coordinates.

The ESRI shapefiles generated from the filtering process were then converted to a raster format using the ArcView function "MakeFromPointStats". In this interpolation method a rectangular window was used in a neighborhood function to assign a yield value to the cell in the output grid. The window size selected had a length of 10-m and a width of 15-m. A cell size of 8-m was selected for the output grid. The yield map from the SVI study area is shown in Figure 7.

Statistical Analysis

The GLM procedure in SAS (SAS Institute, 1999) was used to perform analysis of variance (ANOVA) to test the previously outlined objectives. This method has been proven effective in similar studies for statistical analysis of one-tailed experimental designs consisting of two variables (Kleinbaum et al., 1998). Additionally, all relevant costs were tracked throughout the season and a detailed economic analysis was conducted with the assistance of Dr. David Laughlin, Director of the Agriculture Economics Department at Mississippi State University.

Results and Discussion

There were a total of 15 SVI applications during the growing season. Table 1 shows the dates of SVI applications and the number of acres treated in each application. Also shown are the percent of treated and untreated acres. The total number of acres available for treatment was 1520.83. Of that, only 855.7 acres (56%) were actually treated (Figure 5).

An example of one SVI application is shown in Figure 6. The prescription was generated using imagery acquired on 16 June 2001. Bright red areas on the multispectral composite image (Figure 6a) are indicative of vigorously growing, lush vegetation. The SVI prescription (Figure 6c) is uploaded to the computer on the sprayer and insecticide is applied only to the areas in green. For this particular example, roughly 48% of the field actually was treated with insecticide.

For each of the study fields, the mean yield (pounds of seed cotton per acre) was extracted from each of the grids. These values, along with the fields' treatment designation were entered in a data file and analyzed with SAS. The results of the ANOVA for the yield data are shown in Table 2.

The p-value for the F-test comparing the yields of the SVI and blanket fields was 0.497, indicating no significant difference ($\alpha = 0.05$) in yield between the SVI and blanket treatments. Spatially variable applications of insecticide were able to maintain yields equal to those attained from blanket insecticide applications.

Economic Analysis

An analysis of the economics of SVI was performed to determine the cost savings of using the SVI method over the conventional method. The economic analysis was guided by Dr. David Laughlin, Director of the Agricultural Economics Department at Mississippi State University.

The costs associated with implementing the conventional method include the cost of insecticide material and application costs. Insecticide application costs cover the cost of the spray rig with a 90-foot boom; fuel consumption, diesel fuel cost; salvage, repair, and maintenance costs; performance rate; and operator labor costs. Application costs assume a fully utilized machine. A summary of these costs is presented in table 3.

Additional costs for the SVI method account for spray rig equipment enhancements, remote sensing data acquisition and value added data processing, prescription generation, and management by a service consultant or private precision farming specialist. The additional spray rig costs include the cost of the ruggedized computer, spray controller and miscellaneous GPS equipment. This analysis assumes there are 3 data acquisitions performed in order to provide 3 NDVI scout maps during the June/July time period. This analysis only calls for one SVI application to be performed per field during the season.

The remote sensing data acquisition costs were taken from costs advertised by Agri-Vision. Agri-Vision is a Columbus, Indiana-based company that provides imagery to the precision agriculture industry. The Agri-Vision imagery cost is $1/acre. The data provided by Agri-Vision is band-to-band registered and georeferenced before delivery. The only pre-processing required would be field masking and possibly calibration. There are other companies such as Geotek Management Services at Stennis Space Center that also provide remotely sensed imagery. The $1/acre was used as the raw data collection cost in this analysis. It is assumed that a service such as Agri-Vision will provide the data in a band-to-band registered and georeferenced format. The value added processing costs include estimations for downloading data, masking fields, generation of NDVI image map, materials, and data grid generation. The prescription generation costs include costs for prescription creation, loading the prescription into the spray rig, and downloading and archiving as-applied data. Costs were calculated as "loaded costs" and assume overhead and fringe. These costs have been generated in dollars/acre units and are presented in Tables 4, 5 and 6.

Table 7 summarizes the costs of conventional versus SVI applications. Regardless of the application type, the cost of insecticide (Bidrin in this case) was \$6.80 per acre. The insecticide application cost was \$1.31 per acre for the conventional method and \$1.55 per acre for the SVI method. Additional costs for the SVI method include acquisition and processing of remotely-sensed imagery (\$1.12 per acre) and the cost of a service consultant (\$0.16 per acre). Application costs are shown graphically in Figure 8.

The costs associated with the conventional and SVI applications are shown in Tables 8 and 9, and graphically in Figure 9. In general, the SVI method had a cost savings of 33.19% over the conventional method. For the 855.7 acres treated with the SVI method, the cost was \$8240.39. Had the entire 1520.83 acres requiring treatment been sprayed with the conventional method, the cost would have been \$12333.93. Thus, the cost savings was \$4093.54. If extrapolated to 10000 acres, the cost of the conventional method would have been \$81100.00 and 33.19% cost savings would be \$26916.49.

Conclusions

Insect data collected by the ITD research team was not adequate to test the effectiveness objective. However, preliminary analysis of an additional data set indicates SVI applications effectively controlled insect populations (Willers, 2001). Another fact pointing to the effectiveness of the SVI applications was that no follow-up insecticide applications were required immediately after the initial SVI treatment.

Based on the results of the yield data, SVI applications did not have a negative impact on cotton yields. Similar results were obtained during the 2000 SVI experiment at Perthshire Farms. The consistency of these results is very encouraging as yield levels were maintained across two entirely different growing seasons.

The economic analysis clearly demonstrates that the SVI method is cost effective. Through the use of SVI technologies, the amount of Bidrin saved was nearly 44%. A cost savings of 33% was captured through the use of SVI applications, despite the slightly increased costs of implementing the SVI method.

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Table 1. Acres of SVI fields treated during the 2001 growing season.

Field	**Application Date**	**Field Size**	**Area Treated**	**Area Untreated**	**Percent Treated**	**Percent Untreated**
			acres			
T1316-02	7/5/2001	7.74	5.90	1.84	76.23	23.77
T1316-04	7/5/2001	32.59	11.90	20.69	36.51	63.49
T1316-06w	6/16/2001	208.83	81.10	127.73	38.84	61.16
T1316-06w	7/5/2001	208.83	143.60	65.23	68.76	31.24
T1316-06w	7/27/2001	208.83	144.00	64.83	68.96	31.04
T1316-08	6/29/2001	10.23	7.40	2.83	72.34	27.66
T1316-08	7/28/2001	10.23	7.90	2.33	77.22	22.78
T167-12	7/6/2001	80.80	60.30	20.50	74.63	25.37
T167-12	7/28/2001	80.80	58.70	22.10	72.65	27.35
T167-14	7/5/2001	65.88	41.90	23.98	63.60	36.40
T167-16	6/29/2001	51.79	12.80	38.99	24.72	75.28
T167-19	6/25/2001	157.16	76.20	80.96	48.49	51.51
T167-19	7/5/2001	157.16	92.50	64.66	58.86	41.14
T167-19	7/28/2001	157.16	75.10	82.06	47.79	52.21
T167-20	7/6/2001	82.80	36.40	46.40	43.96	56.04
Average			65.82	47.59	67.20	43.88
Total		1,520.83	855.70	665.13	56.27	43.73

Table 2. Analysis of variance results for yield data.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	161340.507	161340.507	0.49	0.497
Error	16	5284978.205	330311.138		
Corrected Total	17	5446318.712			

Table 3. Insecticide costs for conventional system.

	Unit	Price	Quantity	Total Cost $ / acre
Bidrin	1 oz	$0.68	10 oz	$6.80
Application	1 trip	$1.31†	1	$1.31

† Application costs reflect:

1. 90-foot boom, 800-1000 gallon capacity sprayer.
2. New cost, $173,363.
3. Fuel consumption, 11.71 gallons/hour (diesel).
4. $1.10/gallon diesel price.
5. Includes salvage, repair, and maintenance.
6. Useful life 8 years, 350 hours/year.
7. Performance rate 0.009 hours/acre (average 10 mph).
8. Driver labor cost, SSI and fringe of $8.66/hour.
9. Assumes fully utilized machine.

Table 4. Insecticide costs for SVI system.

	Unit	Price	Quantity	Total Cost $ / acre
Bidrin	1 oz	$0.68	10 oz	$6.80
Application	1 trip	$1.55†	1	$1.55

† Application costs reflect:

1. 90-foot boom, 800-1000 gallon capacity sprayer.
2. New cost, $185,863.
3. Fuel consumption, 11.71 gallons/hour (diesel).
4. $1.10/gallon diesel price.
5. Includes salvage, repair, and maintenance.
6. Useful life 8 years, 350 hours/year.
7. Performance rate 0.01 hours/acre (average 9 mph).
8. Driver labor cost, SSI and fringe of $8.66/hour.
9. Assumes fully utilized machine.

Table 5. Imagery costs for SVI system.

	Unit hours	Price	Acres	Cost	$ / acre
Raw Data Collection	†	†	†	†	$1.00
Value-added Processing	2	$60.00‡	1000	$120.00	$0.12
Total					$1.12

† Imagery cost per acre from Agri-Vision.

‡ Value added processing includes download data, mask fields, NDVI generation, and creation of scout maps for service provider consultant.

Table 6. Service consultant cost for SVI method.

	Unit hours	Price	Acres	Cost	$ / acre
Prescription generation and application	3	$55.00†	1000	$165.00	$0.16

† Prescription generation and application includes consultant or private farm employee to take value added data product and create prescription, load prescription into sprayer, download and archive as-applied data. Price taken from previous years work with precision farming application service provider.

Table 7. Conventional vs SVI summary costs for Perthshire Farms 2001 SVI experiment.

	Method	
Item	**Conventional**	**SVI**
	$ / acre	
Insecticide material (Bidrin)	$6.80	$6.80
Insecticide application	$1.31	$1.55
Imagery	$0.00	$1.12
Service Consultant	$0.00	$0.16
Total	$8.11	$9.63

Table 8. Cost analysis for SVI fields.

	Method		
	Conventional	**SVI**	**Savings**
Cost/Acre	$8.11	$9.63	$-1.52
Acres	1,520.83	855.70	665.13
Total Cost	$12,333.93	$8,240.39	$4,093.54
Percent Cost	100.00	66.81	33.19

Table 9. Cost analysis for extrapolated acreage.

	Method		
	Conventional	**SVI**	**Savings**
Cost/Acre	$8.11	$9.63	-1.52
Acres	10,000.00	5,626.53	4,373.47
Total Cost	$81,100.00	$54,183.51	$26,916.49
Percent Cost	100.00	66.81	33.19

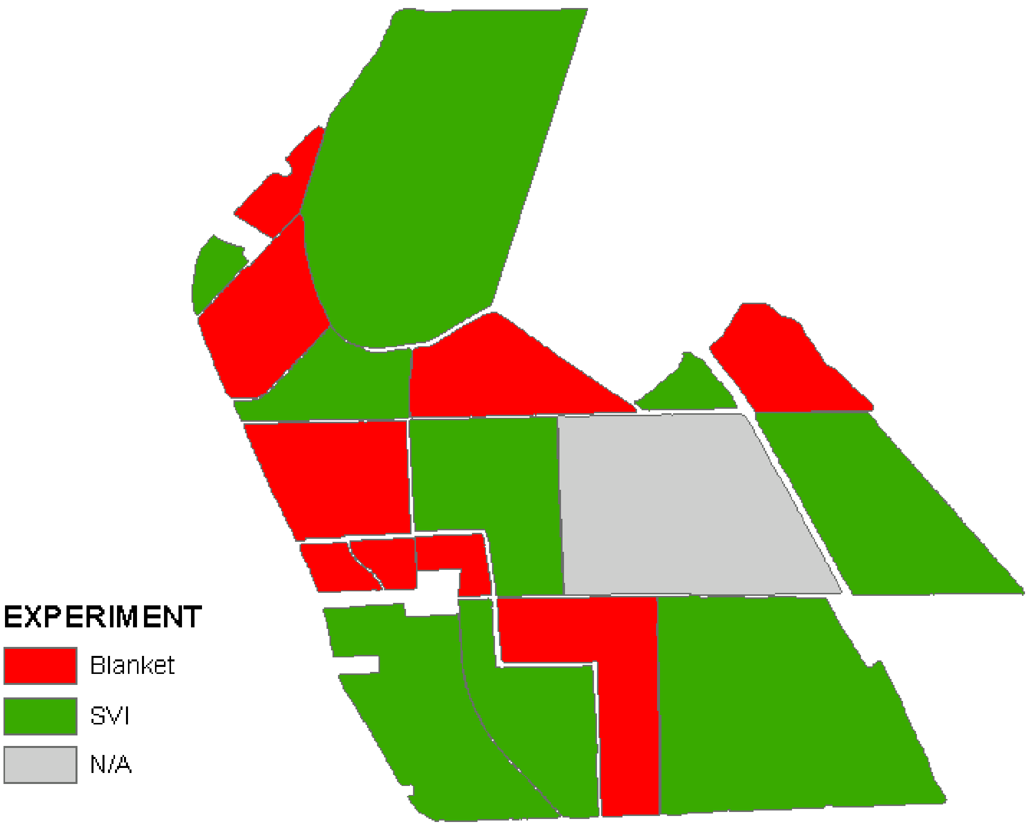

Figure 1. Perthshire Farms 2001 SVI study area.

Figure 2. SVI application with the Case-IH Patriot sprayer.

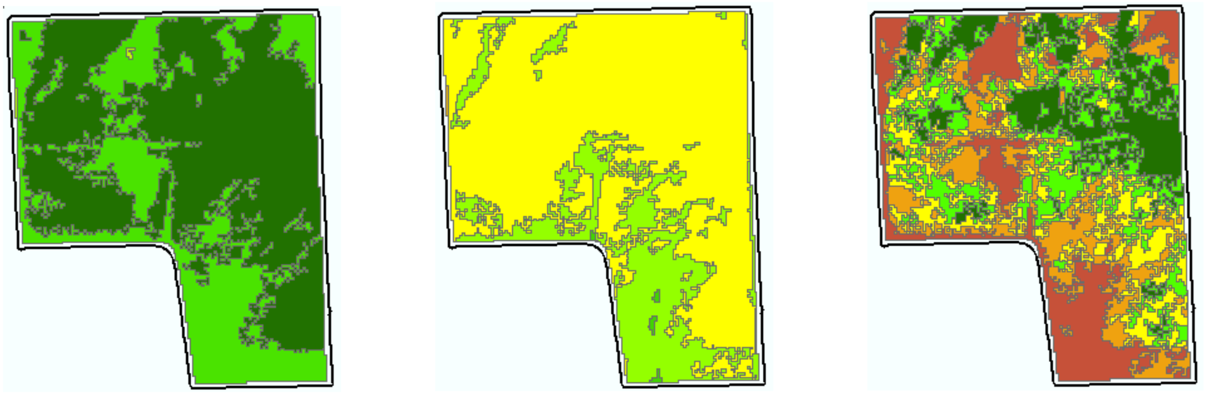

Figure 3. NDVI products created during scout file generation – season adjusted image (left), change image (center), and MaxView image (right).

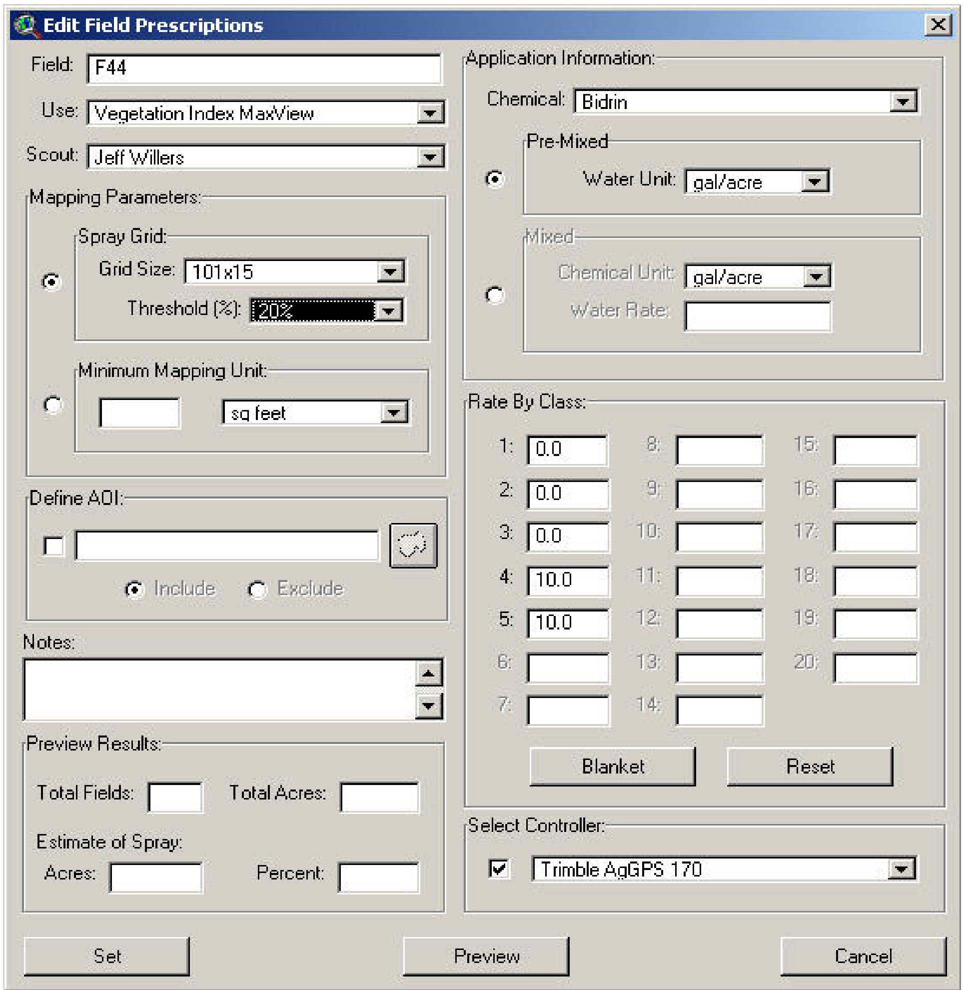

Figure 4. Prescription request form used to specify SVI prescription parameters.

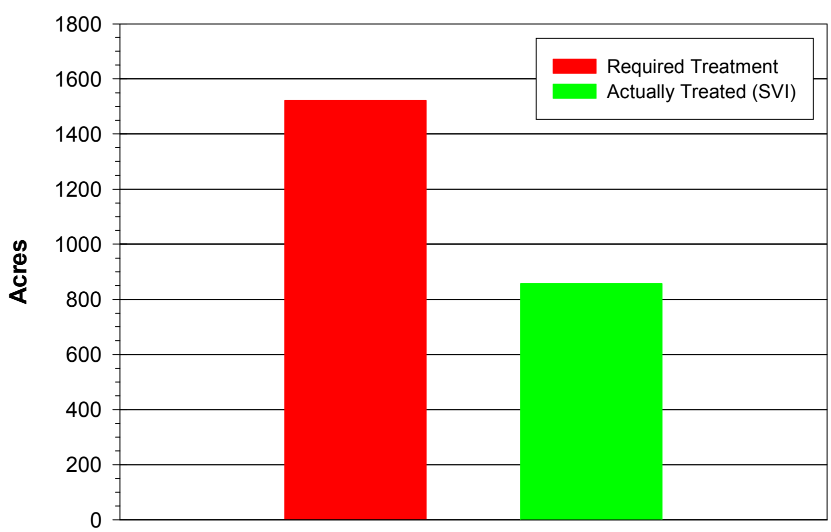

Figure 5. Number of acres requiring treatment and acres actually treated with SVI technologies.

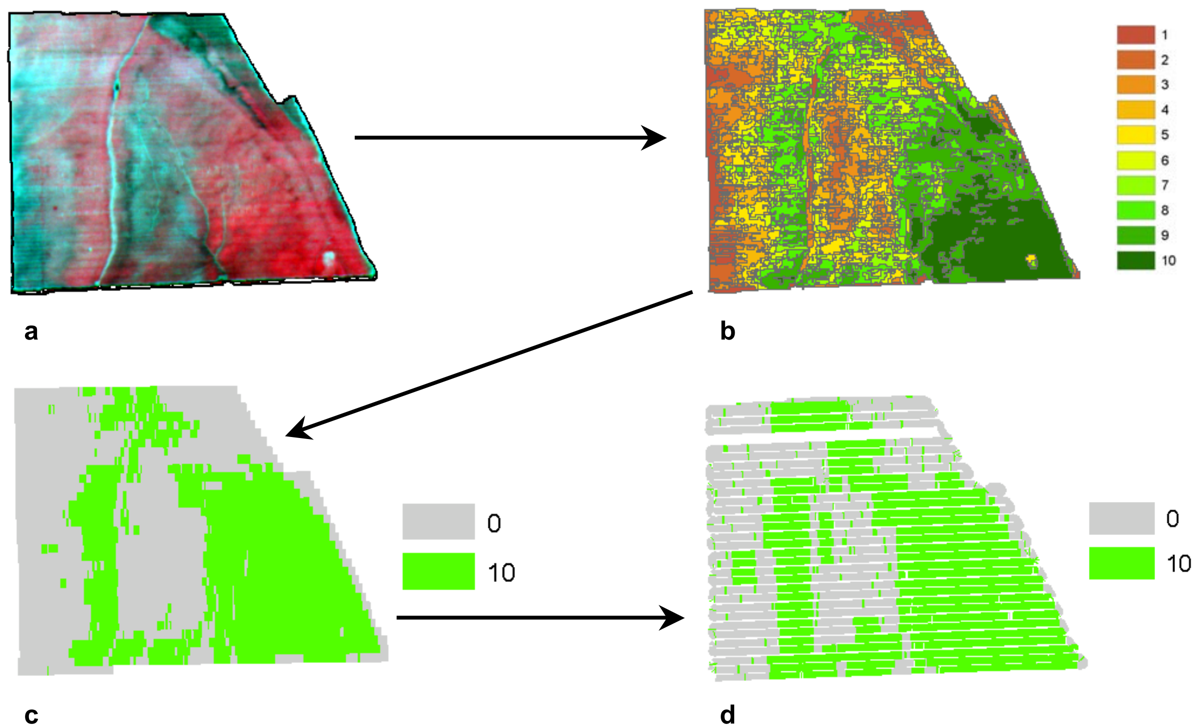

Figure 6. Prescription generation and SVI application for field T167-19 on 25 June 2001. The maps are (a) multispectral composite image; (b) MaxView NDVI image; (c) SVI prescription map; and (d) as-applied map generated by the sprayer.

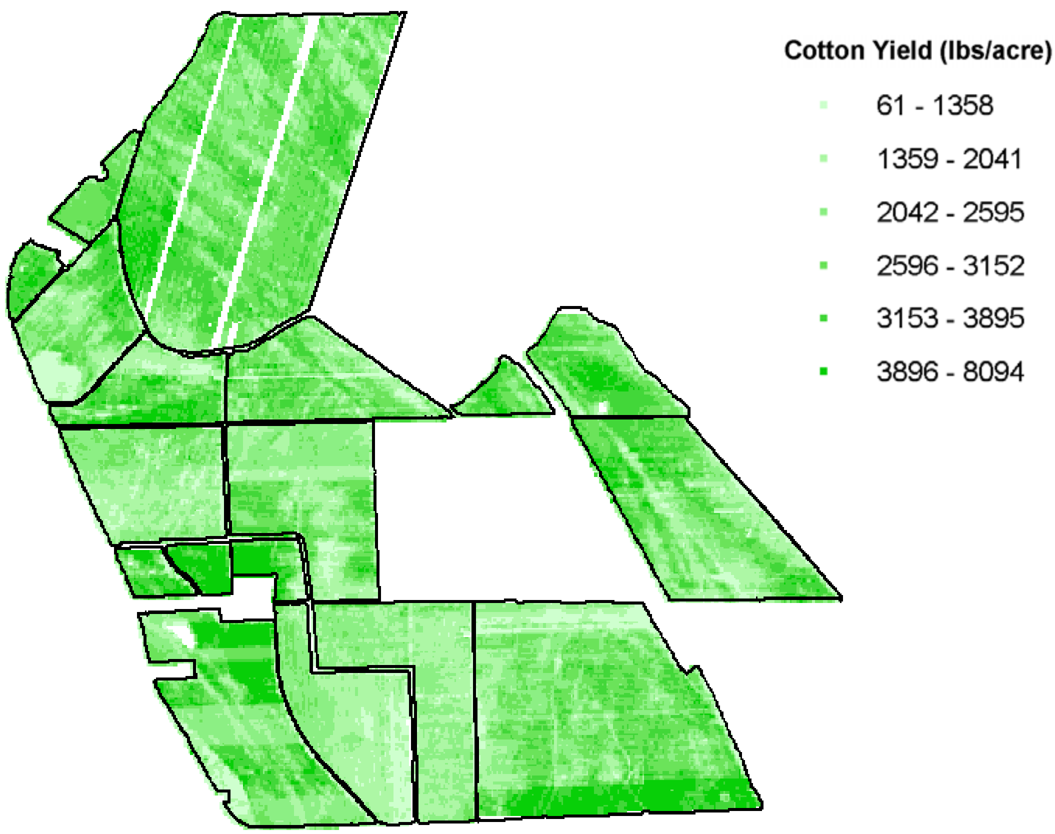

Figure 7. Yield map from the 2001 SVI study area.

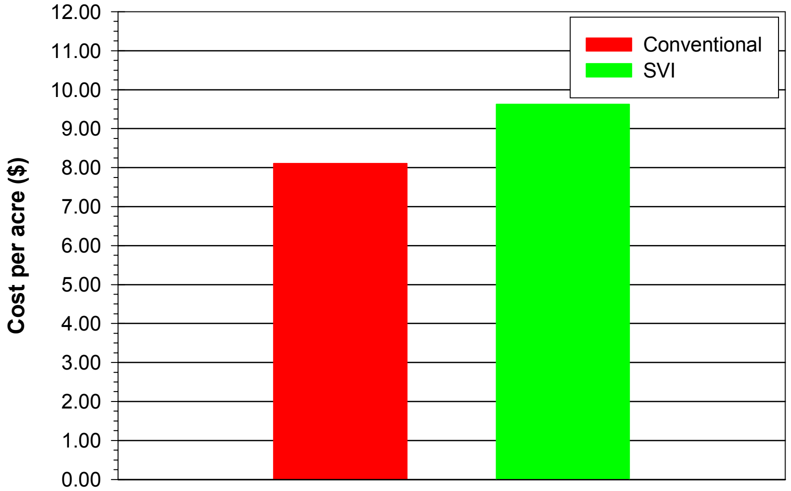

Figure 8. Conventional versus SVI costs per acre.

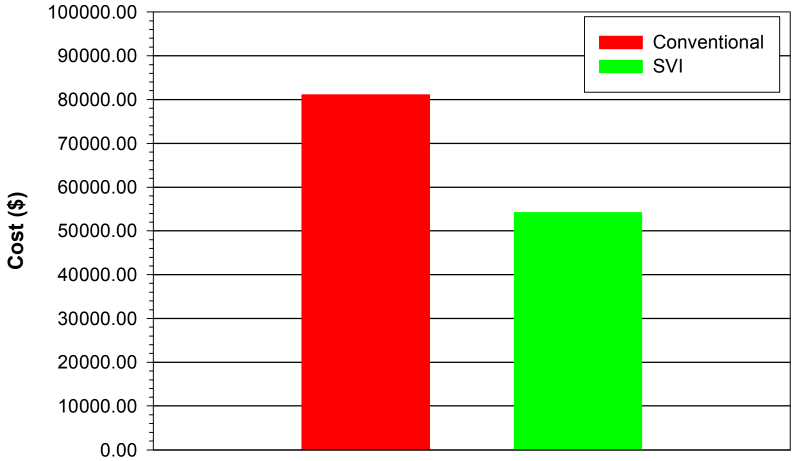

Figure 9. Conventional versus SVI total costs extrapolated to 10000 acres.