ASSOCIATION OF STINK BUG INJURY AND REMOTELY SENSED DATA IN COTTON

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Abstract

Herbivorous stink bugs, some of the most damaging insect pests of southeastern U.S. cotton, are difficult to sample and treat. Remote sensing was explored as a tool to improve sampling of these pests. Two adjacent 36 acre cotton fields were sampled at every acre in 2011 and 2012 by collecting boll samples every week during the critical stink bug management period (third, fourth and fifth weeks of bloom). Satellite remote sensing data were collected during the third week of bloom during both years; NDVI values were calculated for each sampling region. A correlation was investigated between injured bolls at the third and fourth weeks of bloom and the NDVI image from the third week of bloom in 2011. Similarly, a correlation was investigated between injured bolls at the third, fourth and fifth weeks of bloom and NDVI values from the third week of bloom in 2012. There was a positive correlation between injured bolls and NDVI values during the third week of bloom in 2011, but values were uncorrelated in 2012. Injury during the fourth week of bloom was positively correlated with NDVI values in 2011, but negatively correlated in 2012. Finally, injury was uncorrelated with NDVI values in 2012 during the fifth week of bloom. It is unclear why there was a positive correlation in 2011, but a negative correlation in 2012. Remote sensing should be investigated further, in combination with other ground-truthing measurements, to explain these results and for this method to proceed as a useful sampling aid.

Introduction

Herbivorous stink bugs are one of the most important insect pests of cotton in the southeastern U.S. In 2011, an estimated $34 million was lost due to damage from these insects or due to management costs for these insects (Williams 2012). Stink bugs are difficult to manage in cotton because they are peripatetic, polyphagous, spatially aggregated, and some species are tolerant to commonly used pyrethroid-class insecticides (Todd and Herzog 1980, McPherson and McPherson 2000, Willrich et al. 2003, Reay-Jones 2010). In North Carolina, as well as the rest of the southeast, the most common species in cotton are *Euschistus servus* (Say), *Chinavia hilaris* (Say), and *Nezara viridula* (L.) (Herbert et al. 2009).

Rather than sample for stink bugs based on direct sampling, the recommended sampling method is based on indirect sampling of associated boll injury (Bacheler et al. 2010). Recommendations include collecting random samples of quarter-sized bolls, with at least one boll collected per acre; at least 25 bolls should be sampled in each field. Furthermore, it is recommended that this should be done at least weekly from the first week of bloom until cutout. This sampling is time and labor-intensive.

Remote sensing is a precision technology that acquires information about an object without direct contact. Although its greatest applications in agriculture have been in the soil sciences, it has been explored as a detection tool in entomological pest management. For example, another hemipteran insect pest of cotton, *Lygus lineolaris* (Palisot de Beauvois), was shown to be associated with areas of the cotton that were vigorously growing (Willers et al. 1999). These vigorously growing areas were defined by the Normalized Difference Vegetation Index (NDVI), calculated from aerial remote sensing data. The study presented here was designed to examine the potential of remote sensing as a sampling aid to pinpoint areas of the field where stink bugs may have injured bolls. The ultimate goal will be to improve sampling methods and to reduce the amount of insecticides applied by combining remote sensing with precision application technologies.

Materials and Methods

Two adjacent 36 acre fields (cuts) of cotton were selected for the study near Pantego, NC in 2011 (DP 1028 B2RF) and 2012 (DG 2570 B2RF). The cuts were separated by a three-foot ditch and surrounded on three sides by cotton and on one side by a road, with more cotton across the road. Sampling grids were marked every acre in both 36 acre cuts so that 72 sampling points were defined. The sampling points were identified using an eight foot fiberglass pole with a flag attached. Points were marked for later geographical information systems (GIS) post-processing using a Trible GeoXT (Trimble, Sunnyvale, CA).

Cotton was sampled at each point during the third, fourth and fifth weeks of bloom by taking 25-sweep samples with a 16-inch diameter sweep net and, two rows over from the area that was swept, 10 quarter-sized boll samples. Stink bugs were indentified to species at each location and bolls were cracked and assessed for internal boll injury following North Carolina State University extension guidelines (Bacheler et al. 2010). After the fourth week of bloom in 2011, cotton exceeded the recommended treatment threshold guidelines and was sprayed with dicrotophos and *beta*-cyfluthrin (Bidrin 8 at 8 oz/A and Baythroid XL at 3.2 oz/A). Stink bug injury was not detected in the field during the fifth week of bloom in 2011 and data from this week were dropped from the study. After the third week of bloom in 2012, cotton exceeded the recommended treatment threshold guidelines and was sprayed with dicrotophos and *beta*-cyfluthrin (Bidrin 8 at 8 oz/A and Baythroid XL at 3.2 oz/A). Stink bug injury was detected after the spray and was sprayed again after the fourth week of bloom in 2012 using the same chemicals and rates as before. One cut (36 acres) was sprayed using strips, while the other was uniformly sprayed; hence only the 36 sample points from the field with the spatially uniform spray were used for analysis from the fourth and fifth week of bloom in 2012.

Remote sensing data were collected during the third week of bloom on 22 July 2011 using the RapidEye satellite (RapidEye AG, Berlin, Germany) and on 26 July 2012 using a DigitalGlobe satellite, QuickBird (DigitalGlobe Inc., Longmont, CO), both of which were equipped with a pushbroom multispectral satellite. Satellite providers calibrate to refectance from the earth's surface using objects with known units of reflectance and a radiative transfer model with sensitivities for atmospheric scattering and absorption. The frequency of the calibration is proprietary. Satellite data were imported into ArcMap 10.0 (ESRI, Redlands, CA) and regions of interest were drawn around the sampling area at each acre. This encompassed an area that was 36-39 pixels in the RapidEye image (pixel ~54 ft) and 204-207 pixels (pixel ~ 8 ft) in the QuickBird image. Values from these regions of interest were extracted by mask and imported into a an electronic spreadsheet. A NDVI value for each location was calculated using the following equation (Rouse et al. 1974):

$$\frac{(R_{NIR} - R_{RED})}{(R_{NIR} + R_{RED})}$$

where R_{NIR} = the value encompassed in the wavelengths from the near infrared region and R_{RED} = the value encompassed in the wavelengths from the red region.

Correlation analysis (PROC CORR, SAS Institute 2008) was used to investigate the association between boll injury from stink bugs and the NDVI value from each location. Separate correlation analyses for 2011 data were done for injured bolls in the third week of bloom (21 July 2011) and NDVI values from the third week of bloom (22 July 2011) and for injured bolls in the fourth week of bloom (28 July 2011) and the same NDVI values from the third week of bloom. The 2011 remote sensing image did not include all the sampling points and six were dropped from the analysis. Separate correlation analyses for 2012 data were done for injured bolls in the third week of bloom (26 July 2012) and NDVI values from the third week of bloom (27 July 2011), for injured bolls in the fourth week of bloom (3 August 2012) and the same NDVI values from the third week of bloom, and for injured bolls in the fifth week of bloom (10 August 2012) and the same NDVI values from the third week of bloom. Percent damaged bolls were transformed ($\sqrt{(x + 1)}$), when needed, to satisfy the assumptions of the correlation (Zarr 1999).

Results

The main stink bug species captured in sweep samples was *E. servus* (<99%) during both years. Stink bug injury was much lower in 2011 than 2012. For example, there were only 6.2% injured bolls during the third week of bloom in 2011 compared to 28.2% injured bolls in 2012 during the third week of bloom. Even after insecticide treatment after the third week of bloom in 2012, 10.8% of the bolls were injured in the fourth week of bloom. After the second insecticide treatment in 2012, injured bolls were reduced to 2.5%, below the treatment threshold of 10% injured bolls. By contrast, after the insecticide treatment after the fourth week of bloom in 2011, boll injury due to stink bug was essentially undetectable.

Boll injury during the third week of bloom was positively correlated with NDVI values in 2011 ($r = 0.27$, d.f. = 66, $P = 0.0195$, Figure 1) and were uncorrelated in 2012 ($r = -0.02$, d.f. = 72, $P = 0.8570$, Figure 2). Boll injury during the fourth week of bloom was positively correlated with NDVI values in 2011 ($r = 0.45$, d.f. = 66, $P < 0.0001$, Figure 3), but were negatively correlated in 2012 ($r = -0.49$, d.f. = 36, $P = 0.0023$, Figure 4). Finally, boll injury was uncorrelated with NDVI values in 2012 during the fifth week of bloom ($r = -0.03$, d.f. = 36, $P = 0.8824$, Figure 5).

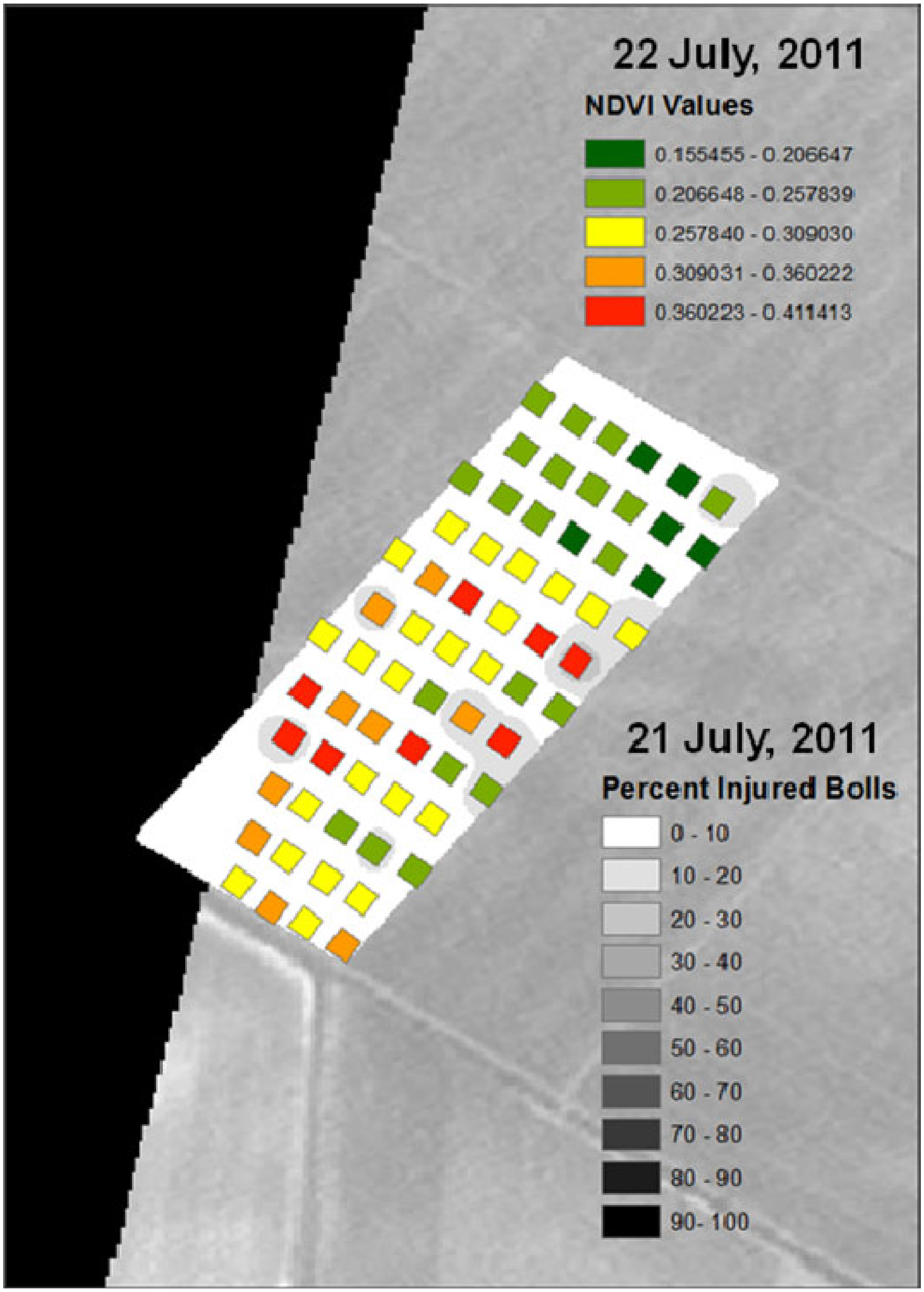

Figure 1. Association of NDVI values and injured bolls from the third week of bloom in 2011. Boll injury is represented as a spatial interpolation. Values were positively correlated. Interpolated values were not used in the analysis, but were simply used as a pictorial representation of the spatial extent of the injury.

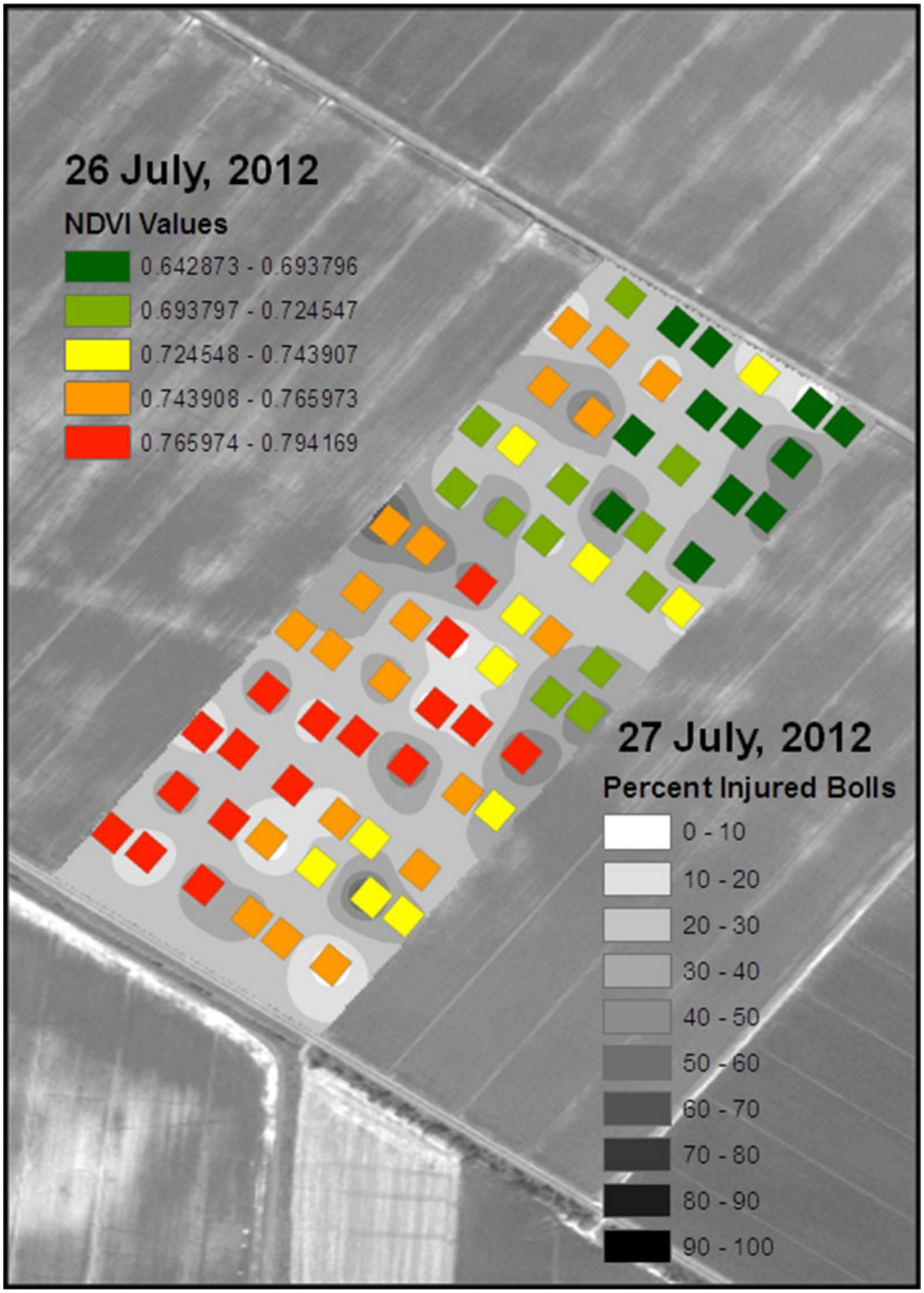

Figure 2. Association of NDVI values and injured bolls from the third week of bloom in 2012. Values were not correlated. Boll injury is represented as a spatial interpolation. Interpolated values were not used in the analysis, but were simply used as a pictorial representation of the spatial extent of the injury.

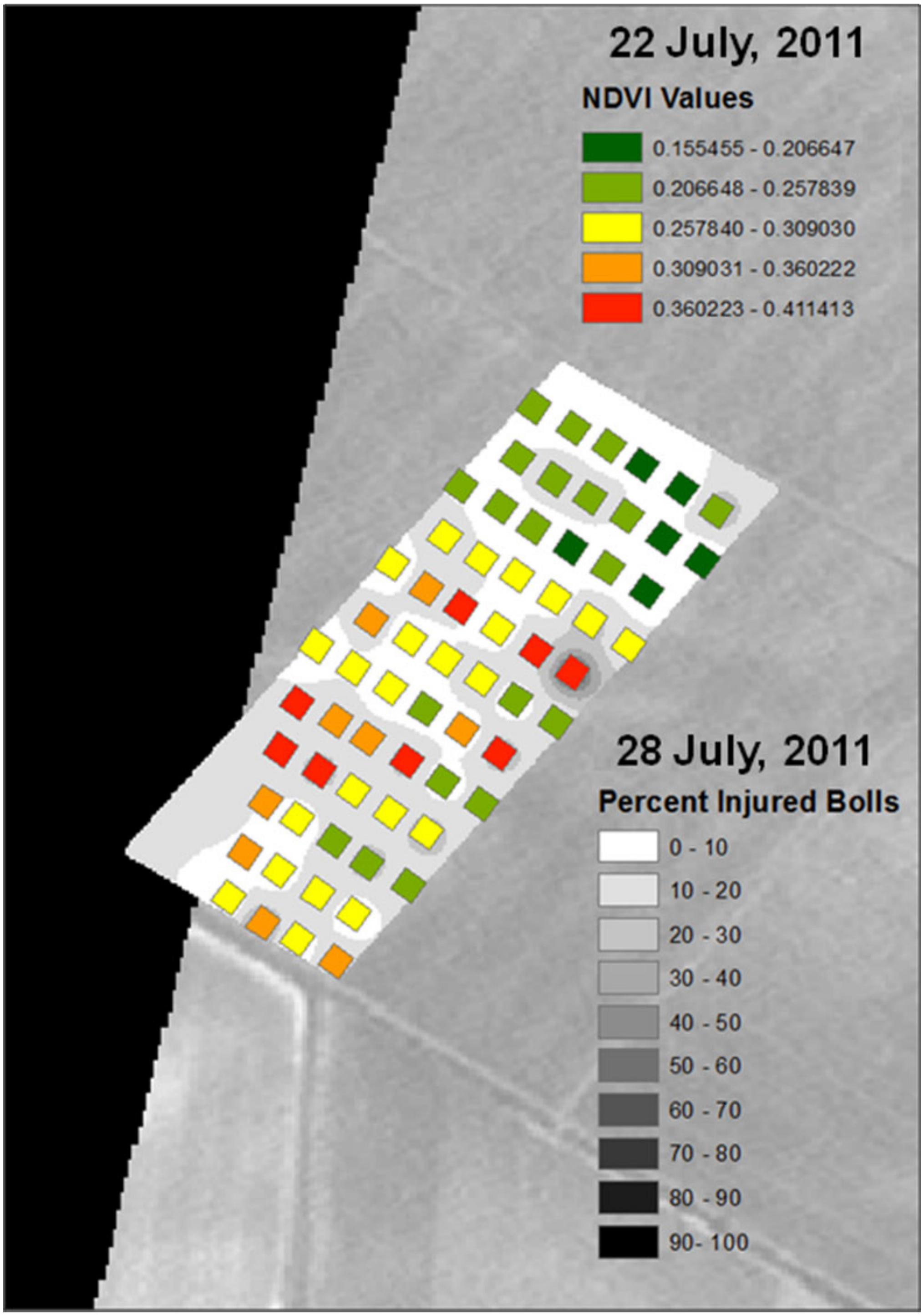

Figure 3. Association of NDVI values from the third week of bloom and injured bolls from the fourth week of bloom in 2011. Values were positively correlated. Boll injury is represented as a spatial interpolation. Interpolated values were not used in the analysis, but were simply used as a pictorial representation of the spatial extent of the injury.

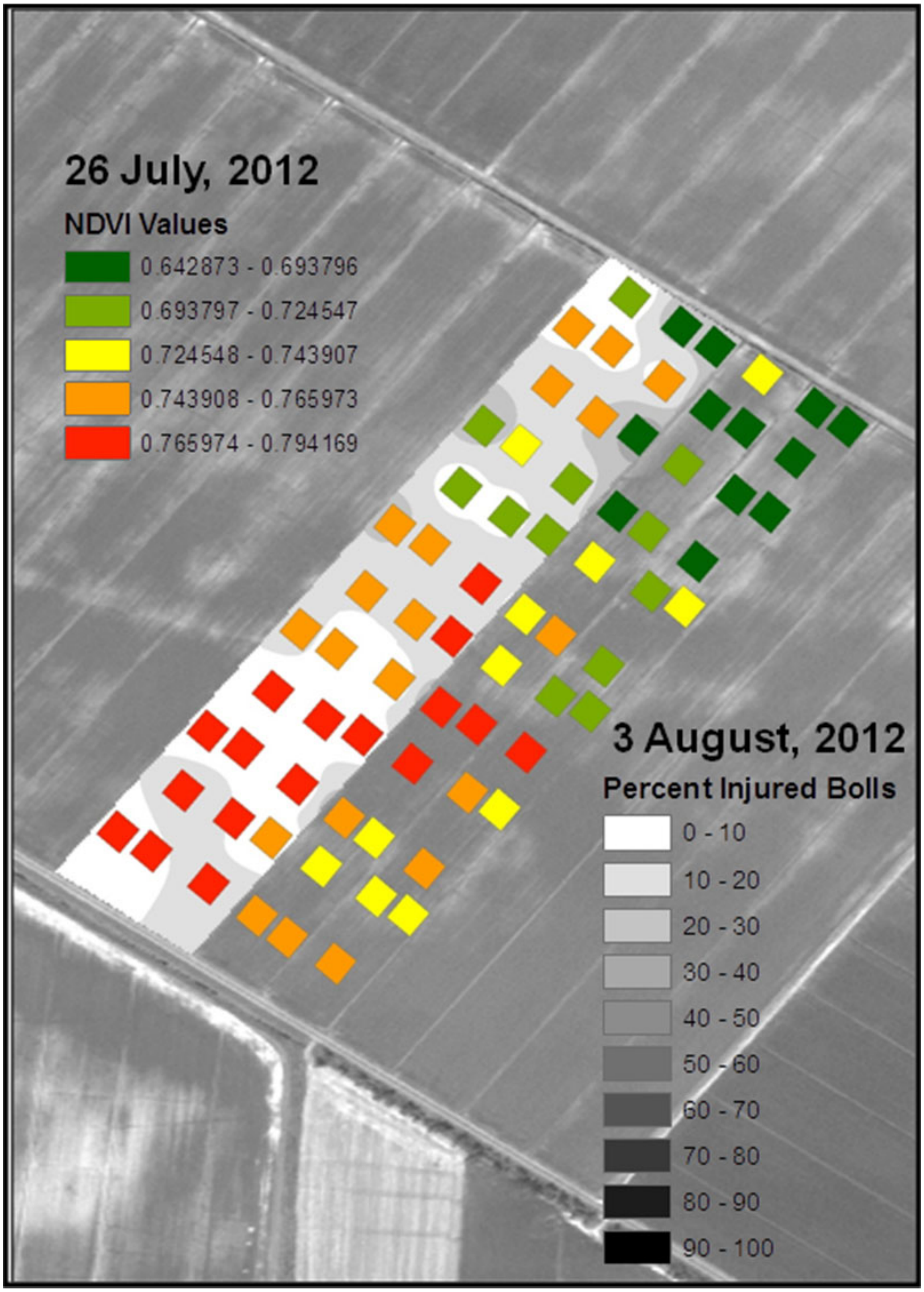

Figure 4. Association of NDVI values from the third week of bloom and injured bolls from the fourth week of bloom in 2012. Values were negatively correlated. Boll injury is represented as a spatial interpolation. Interpolated values were not used in the analysis, but were simply used as a pictorial representation of the spatial extent of the injury. Only the half of the field within the box was used for analysis because it was treated uniformly.

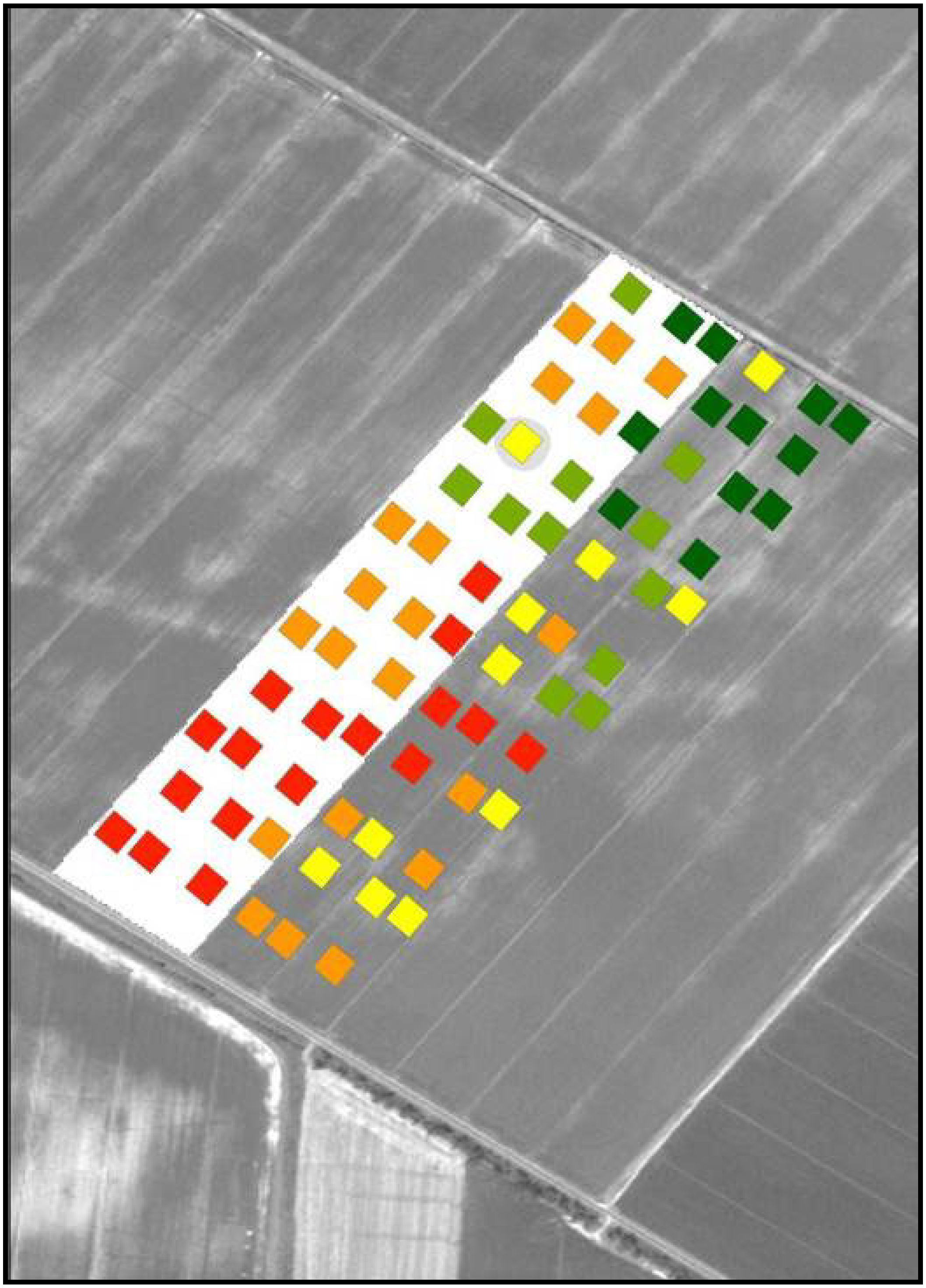

Figure 5. Association of NDVI values from the third week of bloom and injured bolls from the fourth week of bloom in 2012. Values were not correlated. Boll injury is represented as a spatial interpolation. Interpolated values were not used in the analysis, but were simply used as a pictorial representation of the spatial extent of the injury. Only the half of the field within the box was used for analysis because it was treated uniformly.

Discussion

Stink bug injury was associated with NDVI values in this study. The associations were the strongest when NDVI values calculated from the third week of bloom were compared with boll injury from the fourth week of bloom. Because the procedure for determining injured bolls is an indirect method- based on the plant response to stink bug feeding- a time-lag between the phenological stage of the plant and stink bug injury should be expected. However, it is unknown why stink bug injury was more prevalent in areas with high NDVI values in 2011, but less prevalent in the same areas during 2012. Many factors could have contributed to the differences between the two years. For example, the variety in 2011 was an early-maturing variety, while the variety in 2012 was an early-mid maturing variety. Responses in plant growth likely differed in both years due to the interaction of the variety, weather (dryer and more heat units in 2011 compared to 2012), planting date and other unknown factors. NDVI values between both years tended to be consistently relatively lower or higher in the same parts of the field.

One striking difference between the two years was the prevalence of stink bugs in 2012 compared to 2011. It is possible that stink bugs may have been attracted to vigorously growing cotton in 2011, like *L. lineolaris* (Willers et al. 1999) and in 2012. Stink bugs are thought to feed on individual locules from multiple bolls rather than staying on individual bolls and feeding from multiple locules (Willrich et al. 2004). Hence, it is possible that density dependent effects were observed. For example, there was no association between injured bolls during the third week of bloom and the NDVI values in 2012. However, there was an association in 2011. As a result, the third week of bloom could have been a transition period, where stink bugs had injured most of the bolls of a preferred size in vigorously growing cotton and were moving to less vigorous growing areas to feed on previously unfed upon bolls of the appropriate size. Without multiple points of remote sensing data and more data from the crop this is not possible to determine, especially given cotton's indeterminate growth. Future studies should focus on the association among other crop characteristics and stink bug injury for remote sensing to be useful.

Acknowledgements

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