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# Use of a geographic information system to produce pest monitoring maps for south Texas cotton and sorghum land managers

Leonel Deleon [a], Michael J. Brewer [a, *], Isaac L. Esquivel [a], Jonda Halcomb [b]

[a] *Texas A&M AgriLife Research, Department of Entomology, Texas A&M University, 10345 State Hwy 44, Corpus Christi, TX 78406, United States*
[b] *Del Mar College, 101 Baldwin Blvd., Corpus Christi, TX 78404, United States*

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Geographic information system (GIS) tools were used to create pest monitoring maps based on field insect pest monitoring data taken during a two-year demonstration project in south Texas, 2015–2016. GPS-enabled handheld devices with GIS software were preloaded with a basemap and shapefiles containing insect abundance and plant injury data entry lines. Pest monitoring data were entered and stored on the handheld device while conducting otherwise normal pest monitoring activities. The shapefiles were then transferred to a standard desktop computer, where pest monitoring maps were produced using GIS mapping software. Dots using a 5-color scheme were projected and mapped corresponding to the sampling sites. The color scheme represented five different insect density categories relative to the economic threshold of the insect being monitored: green shades were chosen for two categories below the economic threshold, yellow was chosen for a category that included the economic threshold, and orange and red were chosen for two categories exceeding the economic threshold. The insects monitored were cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter), and verde plant bug, *Creontiades signatus* Distant, (Hemiptera: Miridae), on cotton, *Gossypium hirsutum* L., and sugarcane aphid, *Melanaphis sacchari* (Zehntner) (Hemiptera: Aphididae), on sorghum, *Sorghum bicolor* (L.). Pest monitoring maps were created and delivered to land managers within a half-day of data collection. The pest monitoring maps were used by cooperating land managers to better target and prioritize insecticide use to whole fields. Spatial variation in pest density along the field edges was observed. Considering future uses of the spatially variable data portrayed on the maps, a scenario of using insecticides in within-field precision zones matched to sampling sites resulted in a projected reduction of insecticide use (between 40 and 70% depending on the pest) compared with a scenario where insecticides were sprayed to whole fields based on field averages of pest density derived from the same data.

## 1. Introduction

A geographic information system (GIS) provides tools to store, retrieve, process, analyze, and display spatial data and images. Geospatial data refers to any information about a physical area of the world. The data can be collected and displayed with the help of GPS-enabled handheld devices and GIS software (ESRI, 2016; Trimble, 2016). In the case example here, pest and crop field information is collected and projected using shapefiles. After data collection, these shapefiles are projected as vector shapes in a predetermined coordinate system to produce a georeferenced map of the spatial data and images.

Many questions in plant protection have spatial components such as the study of the spatial ecology of insect pests, their crop hosts, and their natural enemies within and between crops. This information can be further linked across landscape features to improve understanding of the pest's regional ecology (Diminic et al., 2010). Spatial analysis supported by GIS tools can play roles in pest management at local and regional levels, such as predicting the spatio-temporal distribution of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Moral-García, 2006), using GIS-based multispectral images to refine pest scouting to guide spatially variable insecticide applications (McKinion et al., 2009), and detecting insect stress in agricultural fields (Nansen and Elliott, 2016). Operational examples are more limited to regional pest risk assessment

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* Corresponding author. Texas A&M AgriLife Research and Extension Center, 10345 State Hwy 44, Corpus Christi, TX 78406, United States.
*E-mail address:* mjbrewer@ag.tamu.edu (M.J. Brewer).

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and detection with services sponsored by industry and government coalitions. Examples include forecasting insect and disease risk (Thomas et al., 2002), regional mapping of insect pest trapping data (Holmstrom et al., 2001; Texas Boll Weevil Eradication Foundation, 2017), and customized mobile applications (Hopkins, 2017; Trimble, 2017).

There are about 400 thousand ha of cotton, *Gossypium hirsutum* L, and sorghum, *Sorghum bicolor* (L.), grown in south Texas annually. In this geographically expansive production system, it is difficult and time consuming for land managers and pest consultants to perform insect monitoring on all fields. In addition to monitoring, it is often difficult to make decisions across different-sized fields using traditional approaches of pest management where exceeding known economic thresholds triggers insecticide use to manage pest insects (Pedigo, 1999). Three primary pests for which between and within field population variation is relevant are cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter), and verde plant bug, *Creontiades signatus* Distant, (Hemiptera: Miridae) on cotton, and sugarcane aphid, *Melanaphis sacchari* (Zehntner) (Hemiptera: Aphididae), on sorghum.

The cotton fleahopper is a key pest of cotton in Texas, Oklahoma and neighboring states. Cotton fleahoppers feed on squares and are prevalent on early blooming stages of cotton growth. They cause square abscission and in high numbers can also cause significant damage and reduction of yield (Parajulee et al., 2006). Cotton damage within and between fields varies spatially, and damage is positively associated with the population density of the pest insect (Ring et al., 1993). Factors influencing cotton fleahopper density include cotton plant vigor, growing conditions, timing of cotton fleahopper movement from non-cultivated weed hosts to cotton, and cotton development stage when the migration occurs (Parajulee et al., 2006).

The verde plant bug is native to the coastal cotton growing regions of south Texas and Mexico. It feeds on cotton and many other plants such as coastal sapweeds, *Saueda* spp., and pigweed, *Amaranthis* spp., that are found near cotton. They tend to feed on young cotton bolls, where they damage developing lint and seeds which can cause boll abscission. In addition to physical boll injury, feeding provides pathways for pathogens that cause boll rot (Brewer et al., 2013b). Much like cotton fleahopper, cotton damage varies spatially and is positively associated with the population density of the insect (Brewer et al., 2013b). Similar to cotton fleahopper, host plants near cotton and insect movement may influence the spatial pattern of this insect within and between fields. Monitoring techniques have been developed for cotton fleahopper and verde plant bug (Parajulee et al., 2006; Brewer et al., 2012), and economic thresholds have been estimated (Ring et al., 1993; Brewer et al., 2013a).

The sugarcane aphid can cause substantial economic damage to sorghum, particularly if infestations occur during vegetative growth (Bowling et al., 2016). Sorghum damage results from a combination of direct loss of plant nutrients and sugars, exacerbation of plant water stress, and reduction in photosynthetic efficiency due to sooty mold buildup from honeydew excreted by aphids. Reduction in number of heads, reduced seed weight, delayed development and maturity, and plant death may result from excessive aphid pressure (Singh et al., 2004). Significant between and within field population variation has been detected (Elliott et al., 2017). Monitoring based on leaf inspection has been used to estimate number of aphids per leaf (Brewer et al., 2017) and to relate the estimate to proposed economic thresholds (Knutson et al., 2016).

In this demonstration project, we first used GIS tools to create pest monitoring maps derived from insect monitoring data, showed the utility of the pest monitoring maps to aid pest management decision-making, and showed the flexibility of the GIS tools in making revisions based on land manager feedback. The pest monitoring maps visually represented insect densities relative to economic thresholds and provided georeferenced locations of the monitoring sites within and across fields. Traditionally, the pest data from field sampling sites would be used to make decisions across the whole field (Brewer and Goodell, 2012). As a second study objective, additional potential applications of using the spatial data were considered. The traditional whole field insecticide use approach in using these data was compared with a precision zone approach of insecticide use guided by using the spatial structure of the within-field insect densities as visualized on the pest monitoring maps.

## 2. Methods and process

GIS tools were used to collect both insect abundance and plant injury measurements. These data were recorded, processed, and mapped to produce pest monitoring maps for delivery to cooperating land managers (i.e., growers and pest consultants) in south Texas during a demonstration project in 2015 and 2016. Value of the maps was considered by acquiring cooperating land manager input and comparing two management scenarios in using the spatial data.

### 2.1. Insect sampling and sample sites

The data were acquired during otherwise normal pest monitoring activities: beat bucket sampling in the case of cotton fleahopper and verde plant bug on cotton (Parajulee et al., 2006; Brewer et al., 2012) and leaf inspection for aphids in sorghum (Brewer et al., 2017). Briefly, a white bucket (18.9 l) was used in cotton to sample for cotton fleahopper during the first three weeks of squaring and to continue sampling for verde plant bug through late bloom of cotton (Brewer et al., 2012). At each sampling site, 40 plants were bent into the bucket and shaken. Dislodged nymphs and adults of each species were counted inside the bucket. The nymph and adult counts across the 40 plants were saved and an average count per plant was calculated using a GPS-enabled handheld device (see section 2.2 below). The number of damaged squares (cotton fleahopper) and bolls (verde plant bug) were also recorded in the devise. Visual leaf inspection was used in sorghum to sample for sugarcane aphid during vegetative growth through soft dough stage of seed head development. At each sampling site, twenty plants (two leaves per plant) were examined, and counts of all growth stages and morphs of sugarcane aphid were visually estimated on each leaf (Brewer et al., 2017). The aphid counts were saved and an average aphid per leaf estimate was calculated using the same handheld device.

The sizes of the fields ranged from 40 ha up to 800 ha. The geometry of the fields also varied from four of five sided polygons to shapes with irregular edges (Fig. 1). Landscape composition was simple with agricultural fields of cotton and sorghum neighboring each other or mixed with natural features such as waterways and mixed grass- and shrub-lands. Sampling sites within a field were selected in consultation with cooperating land managers and spaced at least 90 m apart, with greater concentrations of sites along irregular field edges. During the demonstration, sampling sites were restricted to within 25 m of the field edge per the standard used by the cooperating land managers. Spatial variation along the field edge was mapped by selecting multiple sampling sites, from two to six per field, during each field visit.