DEVELOPMENT OF A COMPUTERIZED EXPERT SYSTEM AS A MANAGEMENT TOOL FOR BOLL WEEVIL ERADICATION

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Abstract

A Boll Weevil Eradication Expert System (BWEES) was developed to incorporate the necessary entomological, agronomical, and logistical elements to support program managers in effectively carrying out area-wide boll weevil eradication programs. This computer-based decision support system is designed to generate real-time tactical decisions for boll weevil eradication management on a local scale. The decision making process is determined by using two main parameters, boll weevil population density provided by means of trapping, and crop phenology in each cotton field. The BWEES is devised to interact with other computerized technologies in accumulating the necessary information for the decision making process. Technologies include the differentially corrected global positioning system (DGPS) for mapping and aerial application of insecticides, and the bar code system for trapping and crop phenology information collection. The BWEES runs on a personal computer in a 32-bit Windows environment connected to a file server utilizing the Novell network operating system and Oracle8 as a client-server relational database. The system can also run on a stand-alone personal computer utilizing Oracle8 Personal Edition.

Introduction

The eradication effort in the United States has evolved from a labor-intensive project relying heavily on human calculation for treatment decisions and other critical analysis, to a highly technical, computerized system currently at work in Texas (El-Lissy, 1996). Since its inception in 1994, the Texas Boll Weevil Eradication Program, the largest single-state boll weevil eradication program to date, has striven to enhance and automate many proven, yet antiquated, methods of monitoring and managing a boll weevil eradication program. By integrating and implementing new systems designed to manage large-scale programs, the Texas program has committed itself to achieving its goal of boll weevil eradication both economically and efficiently.

The expansion potential of the boll weevil eradication program in Texas, which could exceed five million acres at one time, coupled with recent economic technological advances in the area of electronics, compelled us to further develop the current system to an extensive Boll Weevil Eradication Expert System (BWEES). The BWEES is capable of making treatment decisions in real time based on entomological, agronomical, and logistical elements.

The three primary operational components on which any boll weevil eradication program is based are the mapping of cotton fields, detection of boll weevil population (trapping), and control. The BWEES utilizes a diferentially corrected global positioning system (DGPS) for both field mapping and aircraft navigation, and the bar code system in trapping and crop phenology data collection. Finally, the BWEES is designed to maximize the efficiency of program operation by minimizing human error and improving quality control, thus employing fewer personnel.

Materials and Methods

I. Mapping

Mapping is one of the first aspects of operation in any eradication program. The purpose of mapping is to identify the exact location of each cotton field as well as the surrounding environment. Each cotton field in the state is identified with a unique number as discussed previously (El-Lissy et al., 1996). All cotton fields are mapped using DGPS.

Global Positioning System (GPS)

The Global Positioning System (GPS), developed by the U.S. Department of Defense (DOD) as a national defense communication mechanism, has emerged as an all-important tool in agriculture. In a battle of a different kind, the Texas Boll Weevil Eradication Program is utilizing DGPS to identify the precise location of every cotton field and the surrounding environment (El-Lissy et al., 1996). Program personnel use hand-held receivers (Scout Master, Trimble Navigation, Sunnyvale, CA) capable of receiving satellite signals and calculating precise reference points to triangulate a location (latitude/longitude) (Figure 1).

By measuring the travel time of signals transmitted from each satellite, the GPS receiver computes its distance from that satellite. With distance measurements from at least three satellites, the hand-held units can calculate the latitude/longitude within ±100 meters (error range) from the exact location. This inherent error system, generated by the DOD because of the strategic importance of location information, limits the accuracy of the satellites' signals to civilian receivers. A deliberate degradation is created by introducing a random distortion of the signals sent by each satellite called Selective Availability (SA). The U.S. Government has proclaimed that the level of SA will be reduced to zero within the next nine years, possibly as early as the year 2000. In the interim, the Texas program overcomes the inaccuracies caused by SA and the physics involved in sending radio signals through the earth's atmosphere by utilizing DGPS. This reduces the SA error to 1-5 meters.

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The Texas program uses two types of differential correction systems: Real-Time Differential on more than 90% of the acreage and Post Processed Differential on the remaining 10%. The Real-Time Differential service in Texas is provided by two major companies, including Differential Corrections, Inc. (San Jose, CA) and ACCQPOINT Communications Corporation (Irvine, CA) (Abousalem et al., 1995). Each of these providers maintains a network of known positioned FM ground stations (reference stations) sprinkled around the State. The ground stations broadcast an extra signal, which allows the GPS to cancel out many of the inherent errors. The FM auxiliary receiver (DCI 3000® or ACCQPOINT™) is connected to each of the GPS units to calculate and reduce the error to 1-5 meters.

Using the DGPS hand-held units, latitude and longitude readings are taken at every corner (point) around each field. Points are stored in the GPS hand-held units, taken to the office, and downloaded into MapInfo Professional™ version 5.0 (mapping software). MapInfo is then capable of taking the readings, drawing the exact shape and location of each field, and superimposing layers of geographical maps. Each layer provides a detailed map of counties, streets, rivers and other major or permanent fixtures, producing a comprehensive map for each work unit (Cotton Map). These maps indicate the exact location of each field with an error range of 1-5 meters, as well as the exact number of acres within each field. Cotton maps are stored in the computer and used for trapping and insecticide applications, as well as other program activities (Figure 2).

In areas where the FM differential correction service is not available, GPS data is collected in the field utilizing a hand-held GPS receiver (GeoExplorer II, Trimble Navigation, Sunnyvale, CA). Information is then transferred to the office computer using Pathfinder Office software (Trimble Navigation) and saved, and the differential correction is added the following day. The differential correction information is imported from the National Oceanic and Atmospheric Administration (NOAA) FTP Internet site. This approach is known as Post Processing Differential correction.

II. Trapping

Trapping is the primary method of boll weevil detection in any eradication program. The Texas program has been utilizing the bar code system since 1995 (El-Lissy et al., 1996).

Field Data Collection Using Bar Codes and Bar Code Scanner

The Bar Code System is utilized in the Texas program as a tool to assist field personnel in collecting all trapping information in an efficient and timely manner before treatment decisions are made. Each trapper is provided with a 4.1" X 2.6" X 0.6" hand-held bar code scanner (TimeWand® II, Videx, Inc., Corvallis, OR) equipped with a built-in real-time clock to record the time scanning (trapping) took place. The bar code scanner weighs about 4.9 ounces, and is fabricated with a special circuitry that allows scanning in complete darkness and direct sunlight. The scanner also features a 2-line X 16-character liquid crystal display (LCD) window, and an alphanumeric keypad. The scanner is powered by a rechargeable (overnight) nickel-cadmium battery, and equipped with a 320K RAM memory chip allowing it to retain as much as 5 full days of trapping information. The hand-held scanner was designed to tolerate high temperatures (122°F), and humidity (95%), and is built with a durable metal casing to withstand the rigors of field activities. The scanner tip is a partially infrared and partially visible beam that is able to search through dust or contaminates to read the bar code (Figure 3). The bar code (BarCode Labeler™ II) is made of a polyester/vinyl label with smudge proof, carbon-based ink able to withstand the sun as well as multiple scans.

At the beginning of the season, each trap has a unique bar code affixed on the inside wall of the trap body (cup) prior to initial placement in the field (Figure 4). At planting, field personnel scan each trap as it is deployed and enter the work unit, field and trap number using the keypad. The hand-held scanner automatically records and stores the time and date of trap deployment for each trap. At the end of the day, each scanner is placed in a downloader/charger station at the office. Each station is linked to the office computer (PC) with an RJ-11 male connector. The trap information is then transmitted within one minute per scanner to the BWEES database which is designed to match each of the unique bar codes with its designated trap. This process (trap deployment) is designed to establish a permanent record for each trap before the weekly trap inspection begins.

At the beginning of each trapping day, field personnel sign in by scanning their assigned personal identification (ID) number, and then scanning the bar code affixed to their assigned vehicle before leaving the office. This documents the time for payroll purposes as well as vehicle usage. After the sign-in process is complete, the hand-held scanner is then ready to interpret trap bar codes. As each trap bar code is scanned, a series of questions appears on the LCD window. Each question is answered by either scanning a specially configured bar code, or by using the keypad. The questions start by asking the user to identify the task (i.e., deployment, inspection, or removal), followed by the number of weevils in that trap, crop phenology, lure and insecticide strip replacement. Additional questions pertain to trap condition, i.e., trap function, missing or replaced traps, or traps not inspected due to wet conditions. Field personnel scan an end-of-day bar code and place the scanners in a downloader/charger station at the end of the workday. Trapping information is then transmitted to the BWEES for data manipulation and the decision making process.

In addition to trapping information, the bar code scanners serve as a viable method of quality control to verify that all traps are inspected by automatically stamping the actual time of inspection and the exact amount of time spent between traps. Furthermore, the bar code system is also utilized in recording information pertaining to the aerial application of insecticides, i.e., aircraft take off and landing, insecticide usage, and chemical inventory.

Boll Weevil Eradication Expert System (BWEES)

Each of the aforementioned components, while independently valuable tools, are enhanced even further by their integration into a complex computer software program designed within the Texas program to turn raw field data into calculated treatment decisions and fastidious analyses. The primary mission of the newly designed software is to effectively identify fields meeting treatment criteria, generating detailed reports of weevil populations in each field and ultimately compose an extensive treatment history.

The BWEES was developed to run on a 32-bit Windows environment, with Novell NetWare 4 version 4.11 (Novell, Inc., Provo, UT) as a network operating system, Oracle8 version 8.0.3 as a client-server relational database (Oracle Corporation, Red Wood Shore, CA), Seagate Crystal Reports version 7 (Seagate Software Inc., Vancouver, Canada) as a report generating software, and MapX version 3.5 and MapInfo version 5.0 (MapInfo Corporation, Troy, NY) for mapping software. The database consists of three distinct yet interrelated modules including field information, trapping information, and treatment decision information.

The *field information module*, chronicles field number, growers' field name, planting dates for each field, trap number, number of traps around each field, number of acres in each field, grower's name and phone number, agricultural consultant name and phone number, type of environmentally sensitive sites, and contact name and phone number.

The *trapping information module*, which is updated weekly, includes field number, trap number, number of weevils captured in each trap, date(s) of inspection, trap condition when the inspection took place (i.e., functional, nonfunctional, missing or replaced trap, or trap not inspected due to wet conditions), crop phenology in each field, and trapper identification number.

The *treatment decision module*, utilizes certain data elements from the field information and trapping information *module*. Elements include the field number, number of weevils captured in each trap, crop phenology in each field, date of inspection, and date of last treatment (Figure 5).

Daily Utilization of BWEES

1. Data Collection - Once trappers conclude gathering trapping information from scheduled fields on a specific day, the Field Unit Supervisor (FUS) will download the information to the BWEES. The downloading process takes less than one minute per bar code scanner.

2. Data Verification - The BWEES identifies and generates reports indicating fields and traps that were accidentally missed by trappers, prompting the FUS to dispatch trappers to recover the missing information. This process was designed to insure that all fields and traps are inspected according to program criteria.

3. Data Manipulation - The BWEES transmits the stored information to the Cotton Map. Numbers of weevils captured are displayed beside each trap. Fields meeting treatment criteria are selected and color coded red based on a predetermined action threshold. The action threshold encompasses two main parameters:

a. Weevil counts and acreage (i.e., two weevils per 40-acre)
b. Crop phenology (i.e., pinhead square - defoliation)

Other information influencing the selection process includes weevil captures in neighboring fields. This is accomplished by designating a buffer around each trap. The basic methodology of generating a buffer involves adding the weevil counts from traps located within close distance (i.e., 300 feet) to an adjacent field to the actual number of weevils captured in traps placed around that field. For example, if traps placed around field "A" capture one weevil at the pinhead square crop phenology, and a trap located within 300 feet, assigned to field "B," captures one or more weevils, the number of weevils captured in the traps around field "B" will be added to the weevil count of field "A," causing it to meet the action threshold and vice versa.

4. Treatment Decision - Fields meeting treatment criteria are distinguished by a red color and listed in a table positioned on the side of the screen while the rest of the fields remain green. However, the FUS can change the BWEES decision by selecting or unselecting fields by clicking on the individual fields using the computer mouse. When the FUS clicks on a field, a window will appear showing information pertaining to that field including weevil captures in each trap, crop phenology, acreage, date of inspection, and status of each trap (Figure 6). Once the treatment decision is finalized, the BWEES immediately generates color coded maps, a notification listing, and an insecticide application form. The color coded maps indicate fields scheduled for treatment, environmentally sensitive sites, and the designated method of application. The notification listing include grower's name and phone number(s), agricultural consultant's name and phone number(s), and any other special notification that may be required prior to treating a field. The insecticide application form includes all fields scheduled for treatment, acreage, date of application, method of application, the designated applicator or contractor, the type and rate of the insecticide used, and the re-entry period.

III. Control

The control aspect of the eradication program consists of cultural, mechanical, and chemical control. Aerial applications of insecticide are made with airplanes equipped with DGPS technology similar to that used in mapping.

Aerial Insecticide Application

The Texas program relies on the accuracy of precision parallel tracking in all of its aerial insecticide applications and requires all contracted aircraft be equipped with approved and certified DGPS units. Each DGPS unit records flight mission details including the exact position of the aircraft tagged with the date and the exact time, flight pattern, speed, swath width, spray on/off, flight time for each field, and total time for each airplane. At the end of each day, aerial contractors provide the information of each flight on a Memory Card (PCMCIA) or on a standard 3.5" high density computer diskette. The FUS then displays every flight on the computer screen to verify that aircraft are following the specifications outlined by the program. Information is then transmitted to BWEES for record keeping purposes. Four different DGPS units meet the standard specifications required for aerial applications: Satloc Mapstar version 2.08 (Falkenberg et al., 1994); Del-Norte (Landnav®); Precision Electronic Guidance System (PEGS) version 1.6; and WAG TracMap. Each of these systems provide DGPS navigational information with accuracy within one meter (Figure 7).

Discussion

The development and utilization of the BWEES will further enhance the effectiveness of the program, particularly in the area of data management and decision making process. Ultimately this will save the boll weevil eradication program and the cotton producers a substantial amount of money through reduced labor and errors.

This system was also designed to be a user friendly, with minimum training and maintenance requirements. It is important to emphasize, however, that while this artificial intelligence system is an extraordinary helpful tool, it does not supplant the utmost inviolability of trained personnel in carrying out a boll weevil eradication program.

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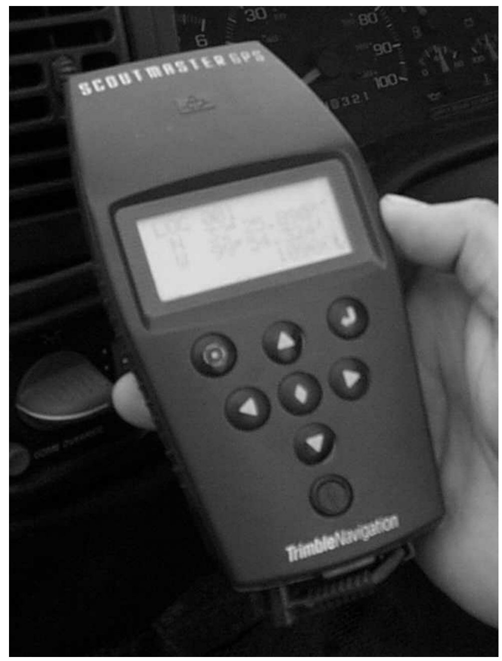

Figure 1. Scout Master Hand-held Global Positioning System Unit (Trimble Navigation).

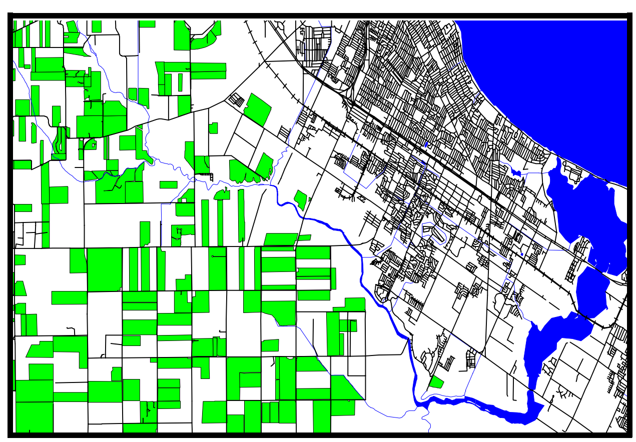

Figure 2. DGPS Cotton Map, Corpus Christi, Texas, 1998.

Figure 3. Hand-held TimeWand® Bar Code Scanner (Videx Inc., Corvallis, OR).

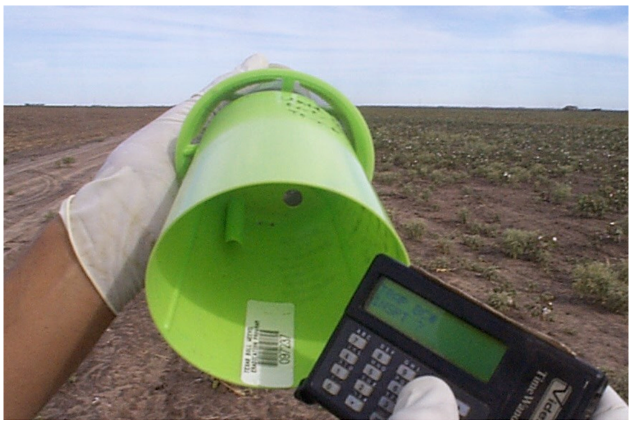

Figure 4. Utilization of the Bar Code System in Boll Weevil Trapping in Texas.

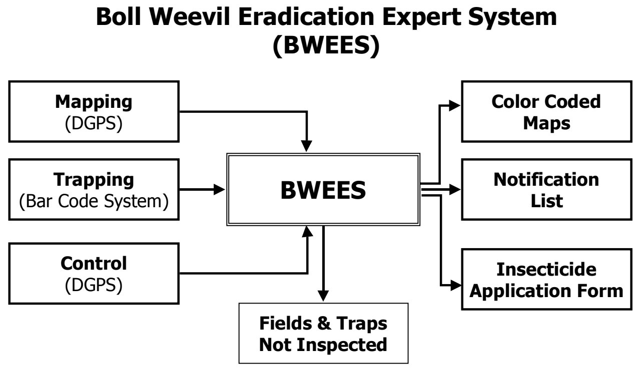

Figure 5. Daily Operation of the Boll Weevil Eradication Expert System (BWEES) in Texas.

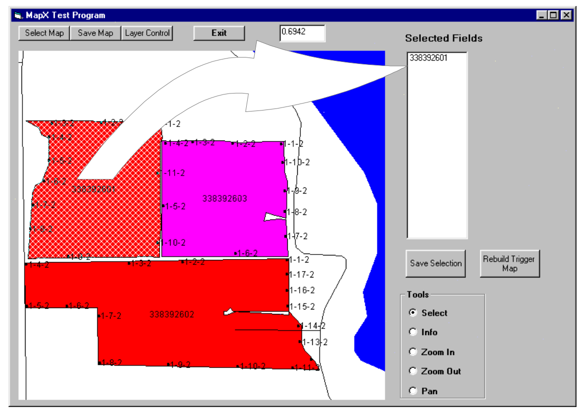

Figure 6. BWEES automated selection of fields meeting treatment threshold based on trap captures, crop phenology and number of acres in each cotton field.