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Evaluation of a Method of Estimating Agricultural Chemical Use

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Abstract

This research evaluated the validity of an economic-based measure of agricultural chemical use on specific crop types. Estimated chemical use measures, reported in a budget planning document prepared collaboratively with input from farmers, vendors, researchers, and representatives from numerous agricultural agencies, were compared to chemical use measures collected through face-to-face interviews with local farmers regarding their actual chemical application practices over the past growing season. A rural agricultural-based county in Mississippi, USA, was the study area for this project. The measures of comparison were the estimated and actual ounces of individual fungicides, herbicides, and insecticides used per acre on corn, rice, soybean, wheat, and cotton fields, and the estimated and actual total chemical load, which is the sum of all fungicides, herbicides and insecticides used on the various crops. To obtain information regarding crop type and area of cultivated land, contemporary satellite images, overlaid with property maps, were plotted and provided for the farmers to identify their crop types and delineate their crop boundaries. The crop boundaries were digitized, and a GIS database was developed containing data for crop types, amounts of cultivated land, and chemical types and quantities used. Outcomes of this research could assist in studies requiring agricultural chemical data by using estimates generated by the USDA and other agricultural agencies as an alternative to primary data collection.
Keywords: validation, chemicals, GIS, remote sensing, farm, agricultural economics.

1 Introduction

This study investigated the validity of published estimations of farm chemical use with actual face-to-face measures reported by farmers in a rural agri-based county in the Mississippi Delta. Estimated measures are well accepted in agricultural forums and are used in many agri-economic, research and farming activities. The United States Department of Agriculture (USDA) National Agricultural Statistics Service publishes the USDA Census of Agriculture [1] every five years, which is a compilation of state and national agricultural data estimates that are routinely used in many farming management and forecasting procedures. The Census of Agriculture contain reported cost and production averages over five years and thus are found to not always reflect actual practice. The Delta Planning Budgets are enterprise budget estimations that are revised yearly based on reports from the previous year. Validation to determine how close these estimated measures are to actual reports by the farmers themselves will help document the use of such economic based measures in non-economic based expanded research including future environmental, health, surveillance, and precision farming applications.

1.1 Study area demographics

This study area was a rural county in Mississippi. Residents are far-flung, with a total population of 2,274 people residing in 733 households on the 449 square miles, about 5 people per square mile. Out of 704 employed civilians who are 16 and over, 64 are farmers or farm managers. Out of 877 housing units, 49 are farms. Figure 1. shows the location of this study area. The University of Mississippi has a long-term relationship with the local community, especially with the farmers. Because of this trustworthy relationship, investigators of this project were able to obtain necessary information from the farming community.

2 Methods

Validation investigations typically compare a measure thought to be less precise with a more accurate measure or "gold standard." In our study, the amounts of farm chemical application reported by the farmers through face-to-face surveys were used as the gold standard and compared with the estimated measures in the Delta 2005 Planning Budgets [2]. Chemical use per acre measures from the Delta 2005 Planning Budgets were used since they integrate actual farm survey data with interdisciplinary and crop specific recommendations [2]. Although produced annually by the Mississippi State Department of Agricultural Economics at Mississippi State University (MSU), these reports represent collaborative input from farmers, farm supply dealers, equipment dealers, custom operators, and chemical companies who provide utilization and pricing data to the Mississippi Agricultural Statistics Service. The MSU Extension Service (MSUES), Mississippi Agricultural and Forestry Experiment Station (MAFES) and the United States Agricultural Research Service (USDA-ARS) are also participants in the development of these budget reports. These budget estimates provide necessary planning data for use by farmers, extension personnel and researchers.

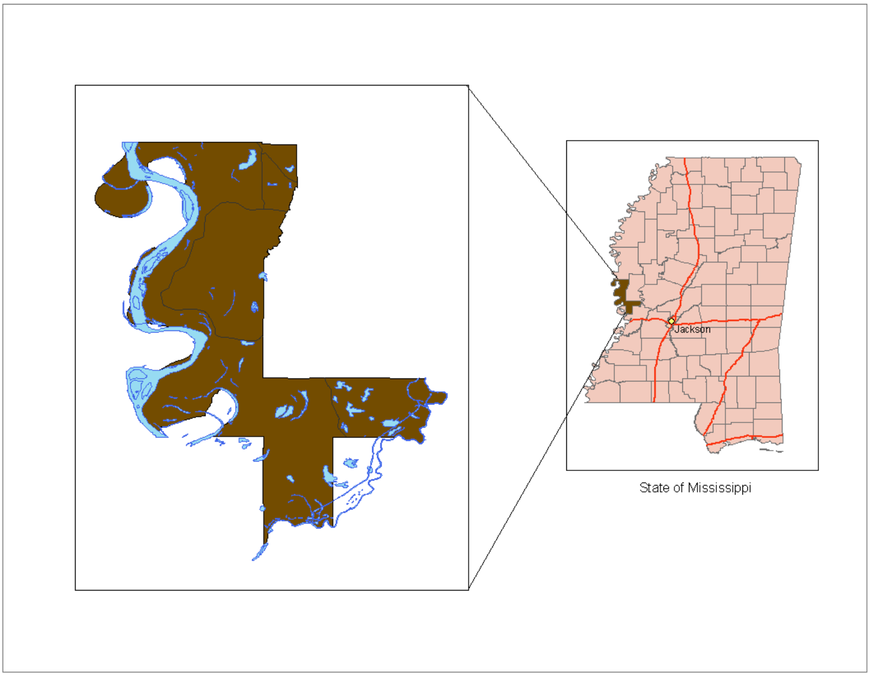

Figure 1: Location map of the study area.

2.1 Rationale for use of estimated measures

In many states farming is a seasonal profession with variable down time. In Mississippi, however, because of the milder temperatures during most of the year, farming activities typically continue throughout the year. Agriculture is Mississippi's number one industry with direct or indirect employment of approximately 30% of the state's workforce [3]. The agricultural economy plays a critical role in the overall economy both for the United States (U.S.) and for Mississippi [4]. Nationally, the net farm income was projected to be over $73 billion, with Mississippi's net farm income making up close to $1.2 billion in the last two years [4]. Mississippi farmers are the experts regarding growing practices and chemical use needed to produce optimal crop outcomes. Most farmers have diverse responsibilities, including supervising and sometimes being actively involved in the planting, irrigation, and harvesting of crops, land and equipment maintenance, adherence to complex and significant numbers of state and federal regulations, and assuring the quality and safety of the food supply [5]. Research investigations support farmers by providing outcome data and reports that help improve overall productivity and operational efficiency, while aiding in prioritizing areas of need. While research efforts can be helpful, in many situations they also require much of a farmer's valuable time. Farmers are asked to provide a magnitude of information and data to numerous agencies for, overwhelming regulatory requirements, futuristic planning and general farm management. Much of the data required are used to develop annual agricultural reports providing average expenditures, costs, crop production and numerous other variables valuable to agricultural personnel. These averages are used as operational estimations for future agricultural activities. Validation of such existing estimations and use of new technologies to expand our information of agricultural applications provide the potential to enhance productivity and decrease the burden on the farmer.

2.2 Use of GIS and remote sensing

For this part of the study, geospatial information technology was used to: a) develop a GIS database for crop types identified during the survey, and b) identify crop types using satellite images. These interrelated capabilities make GIS optimal for such agricultural investigations [6]. During the survey, farmers were provided with satellite images plotted along with property boundary maps. Farmers identified 388 pieces of cultivated lands and delineated their boundaries on the map. These crop boundaries were digitized, and a GIS database was developed containing crop type and chemicals applied on the individual land. A ready to use GIS database for lands cultivated for cotton was provided by the Boll Weevil Eradication Program in Mississippi. This GIS database was used to verify survey information for the lands cultivated for cotton. Figure 2 shows the distribution of surveyed lands with individual crop type. High resolution satellite images were used to identify land use and crop types in the study area. This project had a partnership with DigitalGlobe, Inc. (Longmont, CO) who provided 60 cm resolution of panchromatic (black & white) images and 2.4 meter resolution of multi-spectral images. The electromagnetic bandwidth range for panchromatic is 450 to 900 nanometers, for Blue is 450 to 520 nanometers, for Green is 520 to 600 nanometers, for Red is 630 to 690 nanometers, and for Near Infrared (IR) is 760 to 900 nanometers. Image classification was assisted by the farmer survey data as well as digital pictures taken contemporary to the image acquisition. Satellite images were acquired during the time frame of July 13 to September 18, 2004. The objectives of using these high-resolution satellite images were to develop land use classification as well as crop type classification in the study area.

The USGS land use and land cover classification schema supports four different classification levels to meet the needs of federal and state agencies in land use and land classification throughout the country. The Level I is the most generalized category which categorizes land use and land cover into seven different classes: Crop, Forest, Rangeland, Water, Urban, Barren land, and Wetland. The Level I was used for land use classification in this study. Figure 3. shows the land use classification map of the area. The land use classification strategy included shadow and cloud removal, texture bands calculation, unsupervised classification, and post classification processes. To enable post-classification refinement, a rules-based approach was used for reclassification of non-crop field areas identified by high resolution QuickBird multispectral images. Contiguity analysis and neighbourhood analysis procedures were used to eliminate the salt-and-pepper effect to reduce misclassification in a pixel-based classification method. A region covered by images captured on August 18, 2004 was selected for accuracy assessment using 256 random generated pixels. Overall classification accuracy was 95.31% in this region (Table 1). Crop fields occupy 32.03% of lands in the study area (Table 2).

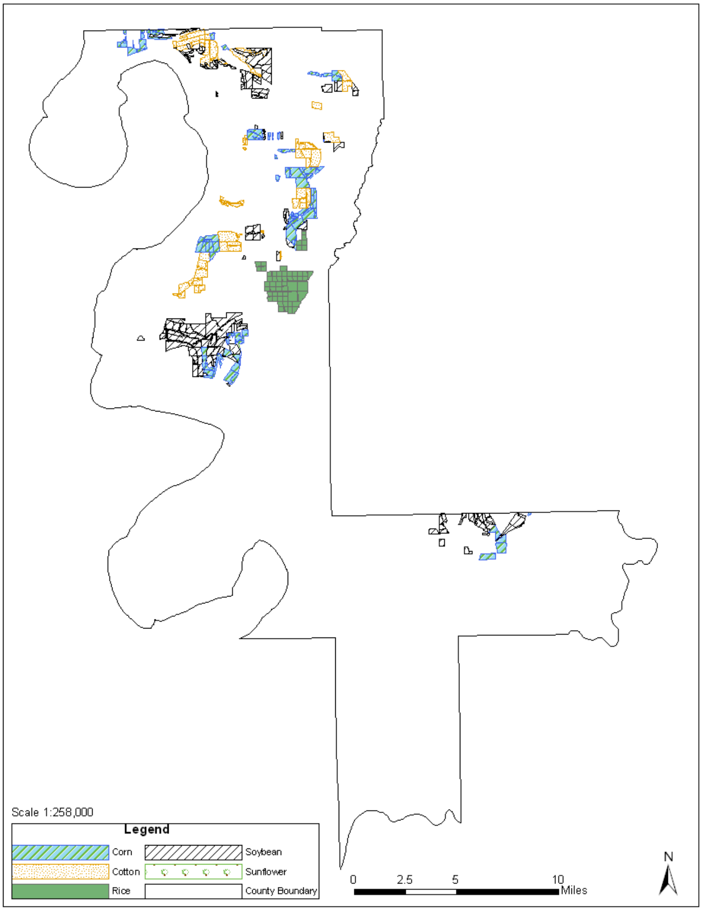

Figure 2: Distribution of surveyed lands with individual crop types.

3 Statistical analysis

Regression analysis and Bland and Altman method [7] were used to compare the survey measures with the standard estimates provided in the Delta Budget report. In regression analysis, the total chemical measures obtained from the survey for each chemical functioned as the dependent variable; and the total chemical standard estimates from the budget report functioned as the independent variable. Realizing that different crop types could produce differing results, correlation comparisons were accomplished by comparing the slope for the different crops.

Figure 3: Land use classification map of the study area.

Table 1: Accuracy of land use classification in one region.

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Crop	120	124	119	99.17%	95.97%
Forest	38	36	35	92.11%	97.22%
Rangeland	33	33	28	84.85%	84.85%
Water	10	8	8	80.00%	100.00%
Barren land	54	55	54	100.00%	98.18%
Totals	256	256	244		

Table 2: Area of land use categories based on land use classification.

Land Use	Area (Acres)	Percentage (%)
Crop	88977.07	32.03
Forest	124124.56	44.69
Rangeland	33733.06	12.15
Water	22071.96	7.95
Barren Land	7852.15	2.83
Wetland	908.71	0.33
Urban	75.80	0.03

3.1 Results

Pearson correlation coefficients (R), slope, and intercept for each chemical were reported in Table 3 as derived from the regression model. As shown in the table, there is little evidence of agreement between these two measurements. In each case, the simultaneous criterion that both the slope and intercept equal zero is rejected (i.e., the line y = x does not fit these data).

Table 3: Measures of agreement and correlation by chemical types.

	Fungicide	Herbicide	Insecticide	Total
R	0.02	0.29	0.13	<0.01
Intercept	2.4 ± 0.3	–222.5±101.3	11.6±5.1	275.2±133.6
Slope	–0.01±0.01	3.6±0.7	0.03±0.06	0.08±0.53

Table 4: Difference of measurements between survey and standard estimates.

Type	Fungicide	Herbicide	Insecticide	Total
Diff ± s.d.:	–21.7±46.9	128.3±802.4	–57.6±56.7	55.8±850.2

As an alternative, Bland and Altman suggest investigating the difference between the two measurements, particularly the variance of the difference. The Bland and Altman method also suggests lack of correlations (Table 4).

The differences between the survey and the standard estimated values show large variances. In addition, the difference is not zero evidencing that there is no agreement. Bland and Altman suggest investigating a type of 95% prediction interval found by using diff ± 1.96 x s.d. [8]. Fungicides appear to be used less often than is recommended as evidenced by the negative difference (–21.7 units), and it appears that the amount ranges from about 114 units below to 70 units above the recommended amount. Similarly, insecticides appear to be used less frequently, on average, than the recommended dose (–57.6 units), and range from 169 below to 53 above the recommended. Herbicides, on the other hand, appear to be used, on average, much more frequently than recommended (128.3 units) and the variance is extremely large (802.4 units). It appears that fields are treated from 1,444 units below to 1,701 units above the recommended amount.

Table 5: Measures of agreement and correlation by crop type.

Crop Type:	Cotton	Corn	Soybeans	Rice
R	0.58	0.21	0.34	0.10

Differences and lack of correlation between the survey amount and the estimated standards were also found when chemicals were compared by crop type as shown in Table 5.

Taken as a whole, farmers may be tolerant of fungi and bugs but they can not tolerate weeds as evidenced by much higher use of herbicides than the estimated values. Overall, our research displays that there is significant difference in measurements of chemicals between the survey and the standard estimates.

4 Conclusions and limitations

Although all farmers were interviewed face-to-face, some reported their chemical application by memory and others referred to written reports they maintain. Both self-reported data and memory are known to have greater margins for potential error than data logs. The Delta Planning Budgets provide estimates specific to the field layout as well as a specific crop. Estimates were provided for cotton and for the specific variety, row layout, irrigation and till method. Farmers typically reported their chemical application per crop type without additional specific information. While this may have affected some chemical application summaries, it should be noted that many chemical application profile estimates are the same for all forms, while others have only minor variations. Traditional farmers are experts at choosing and applying chemicals expeditiously to produce as optimal a crop as possible. Some decisions must be made and adjusted during the growing season to accommodate variable rainfall, usual or resistant pest infestation, and crop rotation. New products that receive regulatory clearance annually would not be reflected in these planning reports. The total for all chemicals for chemical load is limited, because this procedure does not consider the variability in chemical concentration. The budget planning reports provide farmers with estimates of chemicals and harvest outcomes and are respected by the farming community. New and experienced farmers utilize the profiles primarily for cost projections and budgeting year to year. From our results, it would appear that the farmer's expertise and judgment are still the "gold standard."

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