GIS APPLICATIONS FOR THE MISSISSIPPI CROPLAND DATA LAYER, 1999-2006

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ABSTRACT

The USDA's National Agricultural Statistics Service (NASS) conducts a June Agricultural Survey (JAS) across the United States every year. This survey uses field enumerators to visit sample sites called segments. The segment field boundaries, acres, and crops are recorded by the enumerators. This data is uploaded to a NASS GIS software package where field boundaries are digitized to provide ground truth data. This data trains the classifier which examines the set of remote sensing images. Geospatial integration of field and remote sensing data produces a classified Cropland Data Layer (CDL) of the entire state.

Starting in 1999, the Mississippi Department of Agriculture and Commerce (MDAC), and Mississippi State University (MSU) have cooperated annually with NASS to produce the CDL program for Mississippi. The NASS public domain software programs Peditor and RSP and the ESRI ArcGIS® programs are used for data and image processing. ArcGIS applications for Mississippi agriculture include: Segment Locator Maps, Presentation Maps, Website Crop Coverage Maps, and a map for a processing plant location.

ArcGIS maps of Mississippi are used to present agriculture status and conditions in Mississippi over the years 1999-2006. Public access is available via the MDAC and NASS web sites with CD-ROM's available for order. ArcGIS maps have allowed rapid and effective communication of Mississippi data and farming practices for the public, the NASS and State staff, trade shows, and enterprise presentations.

INTRODUCTION

Agricultural land use measured by remote sensing is an important indicator used by the USDA's National Agricultural Statistics Service (NASS) to produce official state and county crop acreage and production estimates in certain key states. These estimates are used to predict the effect of agriculture on the National economy, as input to price determinations, and data for setting Government policies each year. NASS has developed a Cropland Data Layer (CDL) system to classify the location of crop cover types and estimate the acres of each major crop (Day, 2002; Hanuschak, Hale, Craig, Mueller, and Hart, 2001; Mueller and Ozga, 2002).

Mississippi agricultural land use has been measured on a state level using satellites since the early 1980's (Allen and Hanuschak, 1988; Ozga and Craig 1995). In 1999, NASS, the Mississippi Department of Agriculture and Commerce (MDAC), and Mississippi State University (MSU) entered into an agreement to cooperate to produce the Mississippi CDL on a personal computer platform in Mississippi using the NASS public domain

software programs Peditor and the Remote Sensing Project (RSP) segment data manager. These programs were developed in the 1970s from the LARSYS software from Purdue University and were applied to the Mississippi Delta (Craig, 1993; Graham, 1993). Results for 1999-2004 have demonstrated the effectiveness of this program in Mississippi for agricultural land use monitoring (Shore, Gregory, and Mueller, 2005b). NASS expanded the scope of the CDL program in the late 1990's by partnering with other Federal/State government agencies and University groups who were interested in contributing human resource or other capital means toward building a cooperative CDL project within their own state.

The process begins with the intensive June Agricultural Survey (JAS) that consists of on-site field data collection and serves as a vital part of the estimation process. Each June, the field enumerators collect data from specific fields in selected segments during a 2-week period for the JAS. Direct expansion of the JAS data yields the crop acreage estimates prepared for every state on an annual basis. The JAS data is the ground truth used as input for the remote sensing based CDL project. The ground truth data are clustered using the ISODATA algorithm by cover types and are used to develop unique signatures. A maximum likelihood classification is derived from the clusters. Multi-temporal satellite images comprised of scenes taken early and late in the growing season produce improved crop signatures (Allen, 1990; Shore, Gregory, and Mueller, 2005a).

In Mississippi, 298 segments were chosen for the JAS in 2005 from the new area frame generated in 2004. The area frame is selected using satellite imagery to stratify the land based on agricultural intensity. Segments are about 1 square mile and are statistically chosen from the area frame. The segment field boundaries, acres, and crops are recorded by the enumerators. This data is uploaded to a NASS GIS software package where field boundaries are digitized to provide ground truth data. Images are grouped into analysis districts by date, where images are analyzed by similar acquisition dates. The field data and image data are used to train the classifier by clustering the information to give specific crop categories or signatures used to classify the entire set of remote sensing data. The result is a classified CDL of the entire State.

After preparation of the CDL in Geotiff format, the use of the ESRI ArcGIS® software is important for the process of defining the Mississippi agricultural land use (Shore, Gregory, and Mueller, 2006). The ESRI results are also a communication tool used by the team of the NASS Research and Development Division in Fairfax, VA, The USDA-NASS Mississippi Field Office in Jackson, Mississippi, the MDAC in Jackson, Mississippi, MSU in Starkville, Mississippi, the Field Enumerators located throughout the State of Mississippi, and our clients. For example, the NASS Research and Development Office send the Mississippi Field Office segment center maps and segment shape files for locating and mapping segments.

The Cropland Data Layer annual product is published on CD-ROM and is available shortly after the county estimates are released in late July of the following year and can be obtained by calling (800) 727-9540 or on-line at http://www.nass.usda.gov/research/Cropland/SARS1a.htm. The Mississippi Cropland Data Layer products are also available in state and county map high low and high resolution JPEG form, produced using ArcGIS, for the period 1999-present at http://www.mdac.state.ms.us/.

DATA COLLECTION

The USDA-NASS June Agricultural Survey

The JAS is conducted in the first two weeks of June when all segments are visited by a field enumerator. The JAS is a probability based area survey based on a stratified area sampling frame and is used by NASS to produce annual planted acreage estimates. Mississippi segments are selected by NASS Headquarters, from their Mississippi Strata and are distributed over the State with emphasis on the more intensively cultivated strata (Figure 1). During the JAS, the field enumerators draw off each field boundary on a 2' by 2' aerial photo at 1:8,000 scale of the chosen segment and they collect attribute information about the each field and the operation of the farm onto a questionnaire. The questionnaire is keypunched by NASS staff, and serves as the basis for the CDL's ground truth. In 2004, a new area frame was prepared to reflect the changes in Mississippi agriculture and to isolate aquaculture ponds from the selection process to increase the number of different agricultural crop fields. A smaller number of segments were selected in 2005 (298) than in 2004 (356), providing nearly 60 less square miles of training fields. Figure 2 is a side-by side comparison of one county for the 1999 and 2004 stratum. Segment locator maps (Figure 3) are prepared in the Mississippi Field Office (MS FO) using ArcGIS. The data layers used for these maps are the segment boundaries, other geographic information such as the National Forests from www.maris.state.ms.us, and

the county map CAD files obtained from the Mississippi Department of Transportation. The major advantages of these maps are the small size (11" x 17"), readable font size street names, and landmark locations including churches and bridges in the immediate vicinity of the segments The RSP program is used to digitize field outlines on satellite images as shown in Figure 4 and helps clean up field boundary errors from enumeration.

In 2005, three field supervisors piloted use of the USDA-Farm Service Agency (FSA) 1-meter color aerial images and field boundaries (with segment outlines superimposed using ArcGIS) as quality control checks on the field data. These maps will probably be used by all Mississippi Field Supervisors in the future. FSA data has been used in NASS Field Offices for prescreening for the JAS and for other surveys. Presently the Mississippi NASS Field Office is using the FSA State data for updating the List Frame estimates and has done one smaller area frame project with FSA data.

Satellite Images for Mississippi

Landsat 5 and 7 images have 30 meter resolution and are excellent for use with training fields of 10 acres or more. This is also an economical way for state-wide coverage. The United States Geological Survey has an excellent viewer at http://glovis.usgs.gov/. In 2004, the Mississippi CDL was done using just 3 analysis districts vs. the 5 analysis districts needed in 2005. Analysis districts are defined as scenes that were collected on the same day, (i.e., four multi-temporal scenes collected over central Mississippi will have the same base/primary date 5/21 and same secondary scene date 8/2 for instance). Extra analysis districts are required if cloud-free scenes are not available. Recently NASS has started use of the Indian Remote Sensing (IRS) ResourceSat-1 Advanced Wide Field Sensor (AWiFS). The AWiFS scenes cover a larger area with lower resolution (56-meter average resolution) have similar spectral properties (comparable to Landsat TM bands 2, 3, 4, and 5) and have a repeat visit time of five days. In 2005, the Mississippi CDL was also prepared using a single multi-temporal AWiFS scene covering most of the important agricultural areas of the state. The AWiFS scenes were used to prepare some of the final estimates. In the published CD-ROM for the Mississippi 2005 CDL, both the Landsat 5 and AWiFS Geotiff layers will be included for use in ArcGIS.

CROPLAND DATA LAYER PRODUCTS

Mississippi Crop Estimates Obtained from the Cropland Data Layer

Peditor has a highly developed estimation program that uses a linear regression model to match reported field size and categorized pixels against each other, a pixel counting program, and a direct expansion program. The analyst can choose the type of estimation used for a given analysis district and strata. This allows estimations even if an area has few training fields or cloud interference. Statistics are provided to show the variation and percent satellite use per county. The performance of the Mississippi CDL 1999-2005 estimates for the major crops is shown in Figure 5. It shows an overall excellent agreement with the official USDA-NASS estimates. Note that the CDL estimates are provided prior to finalizing the official estimates and are used as an indicator in preparing these estimates.

Single Year Land Use Maps

Estimates are useful but the ArcGIS displays create the most interest in the CDL. A single year map gives the agricultural land use for that year. The CDL not only shows the type of crops grown during a given year, but it captures the spatial extent and distribution of the crop for that growing season across the state. Presentation maps were prepared for the Mississippi Delta (Figure 6) and for State and county areas (Figure 7). These single-year classified maps tell a story, for example, that soybeans predominate in Mississippi crops. In addition, a map was prepared to show location of a processing plant for sweet potatoes using the 2004 CDL data.

Multiple Year Land Use Maps

By using multiple layers in an ArcGIS map, historic land-use patterns reveal land use and allow inferences of land value. For example, cotton is usually grown in the sandier soil along existing or ancient rivers and creeks as shown in Figure 8. This map was prepared by making all layers transparent except cotton, which was made semi-transparent. Also, a picture was included to add additional interest. Similar maps prepared for rice show the effect of rotation on the rice land use (Figure 8). The recommended rotation for rice is one year of rice followed by 2

years of soybeans resulting in comparable maps for the 3-year periods shown. In comparing the single year land use map (Figure 6) with the multiple year successive overlay presentation for the major crops (Figure 9), the land use pattern becomes more evident and can lead to the interesting observation that the more profitable rice and cotton crops could have almost equal acreage in the future.

Image/Map/Statistical Display Posters

NASS generates many useful statistics about Mississippi agriculture that can be displayed in attractive and informative graphs. By superimposing these graphs on top of a picture or map using ArcGIS, impressive posters can be prepared, describing a story or economic circumstance that made an event happen. For example, cotton yield changes during the 1980s were relatively flat but have recently returned to their historic increases (as shown in Figure 10) due to improved farming practices such as high density cotton, the boll weevil eradication program, and the use of transgenic varieties. Mississippi leads the nation in catfish production and displaying a production graph and showing the spatial catfish extent is useful for current or future producers in the catfish industry. Use of ArcGIS also allows printing of large posters without the need for purchasing additional large format software.

RESULTS

The annual Geotiff Cropland Data Layer produced using Peditor and RSP is useful to determine agricultural land use for a given year and for multiple years. With ArcGIS, useful map products have been made including:

Arc GIS presentation maps including those distributed to each of the MSU Agricultural Extension Offices and for web downloads at http://www.mdac.state.ms.us/.

Maps for locating possible agricultural product processing plants showing the field locations.

Trade show exhibit Power Point® and poster displays to add color and interest for Mississippi agricultural stake holders.

Arc GIS Picture/Map/Statistics posters such as those exhibited in lighted displays in the Mississippi Department of Agriculture and Commerce building. These displays are periodically rotated to highlight different Mississippi agricultural land uses.

The final CDL products for all states currently using the process are available from USDA-NASS at (800) 727-9540 and on-line at http://www.nass.usda.gov/research/Cropland/SARS1a.htm.

DISCUSSION

The use of remote sensing to prepare the Cropland Data Layer provides a statistically unbiased measurement of crop acreages and land use, and is a valuable tool for natural resource management. The Landsat and Indian Remote Sensing AWiFS satellite images combined with the NASS JAS provide synergistic effects providing useful and valuable statistically defensible results and a product that is growing in public demand. The CDL program not only benefits the NASS acreage program by providing unbiased statistical estimates of the major crops grown in an county, but it provides a very useful spatial data product in the public domain. Acreage estimates using the Cropland Data Layer trend well over time with the NASS official estimates and give an additional indicator of known good quality to help in developing an accurate crop estimate. ArcGIS maps are useful aids in the collection of data and the preparation and analysis of the Cropland Data Layer product and displays for clients.

Agricultural Departments in nine other states now use the CDL process to make more effective use of the June Agricultural Survey data and produce visual crop coverage maps. Since the CDL program began in its current form back in 1997, twenty two states have been processed at least one time, with one new state (Washington) slated for inclusion into the program for crop year 2006.

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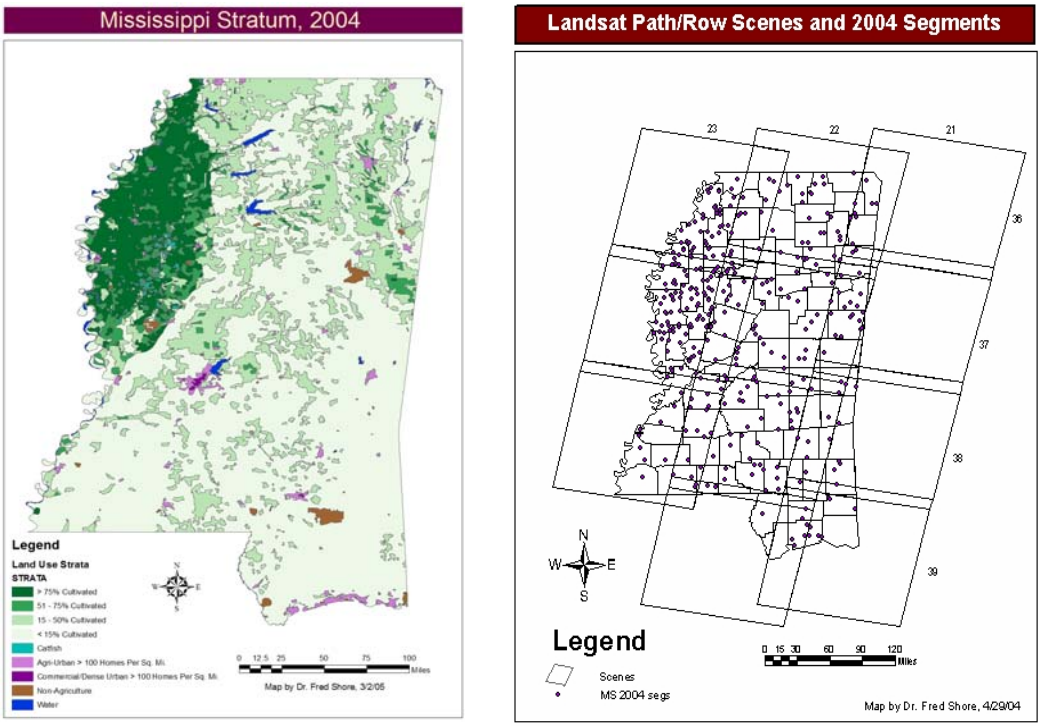

Figure 1. The stratification of land by use allows statistical segment selection to give an expansion estimate for crops of the state. Note that more segments are chosen in the more intensely cultivated stratum.

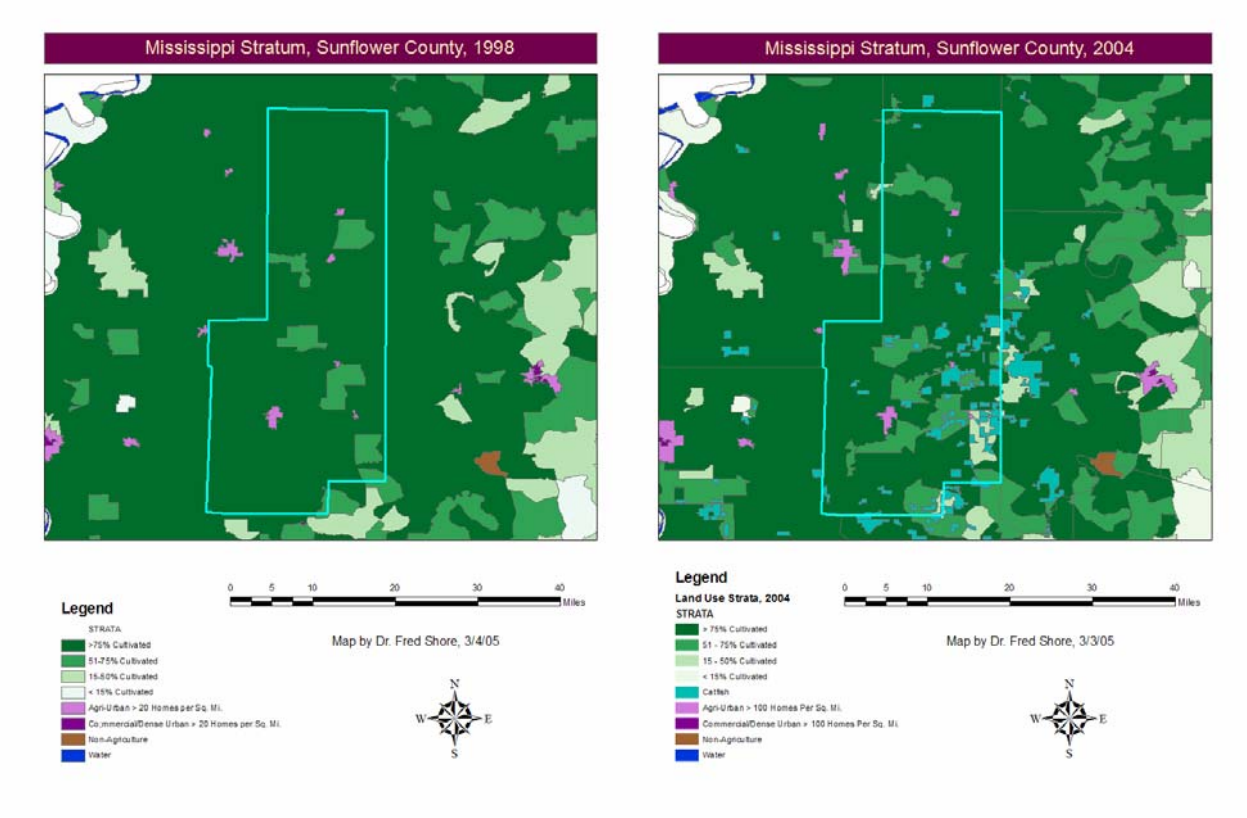

Figure 2. The new sample selected in 2004 was improved by identification of aquaculture ponds.

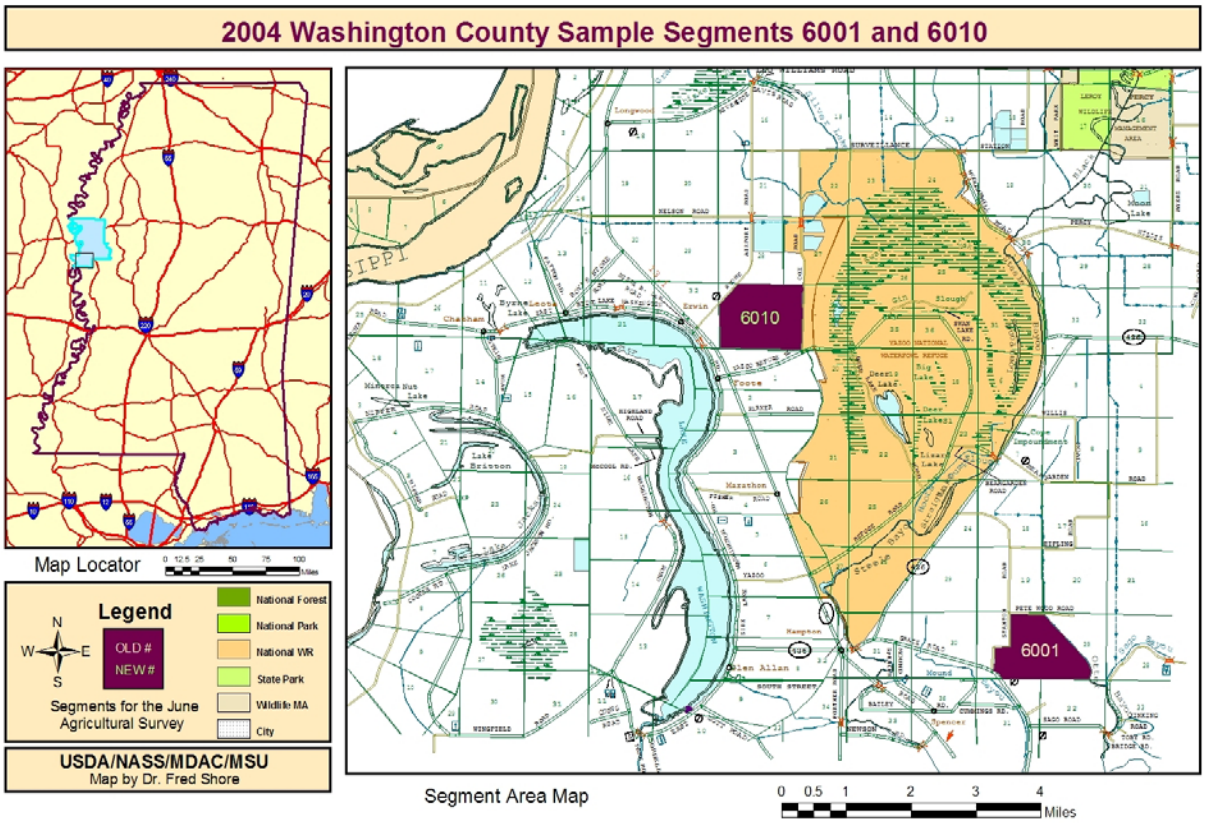

Figure 3. A Map prepared to help the USDA-NASS Field Enumerators find the JAS study segments.

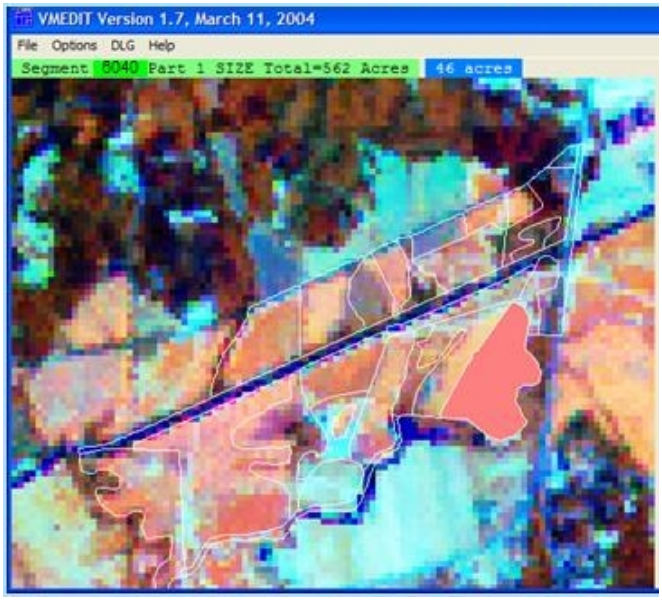

Figure 4. RSP allows field outlines to be superimposed on images and acreages measured.

Mississippi Major Crop Planted Acres Estimates, 1999-2005
Cropland Data Layer Value as Percentage of the Official Estimate

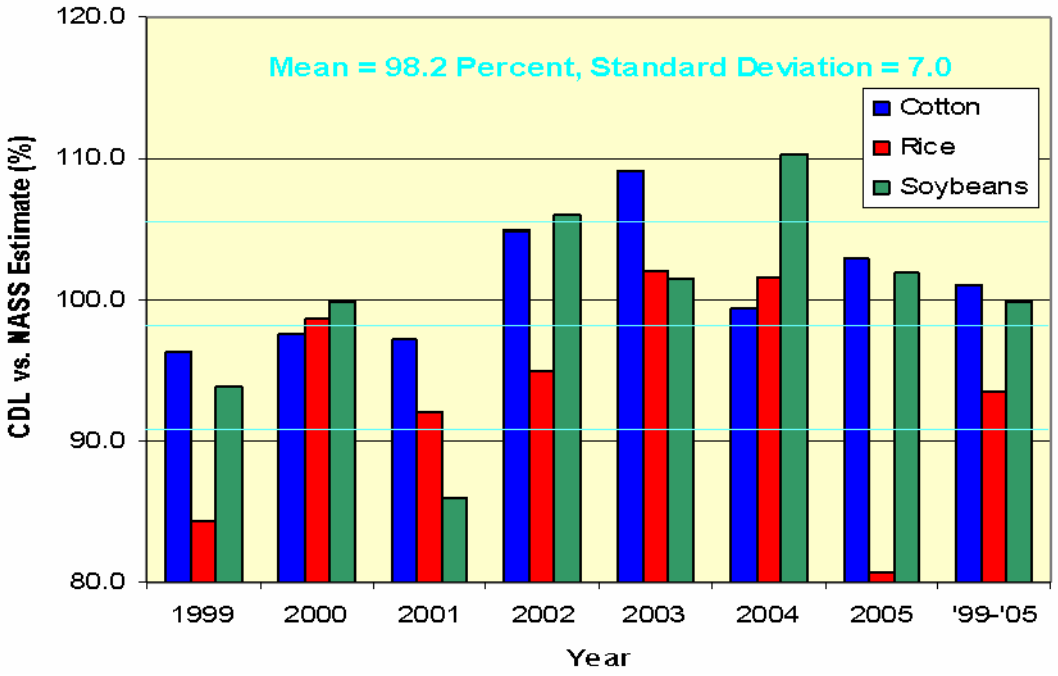

Figure 5. Estimation performance for the Mississippi Cropland Data Layer, 1999-2005.

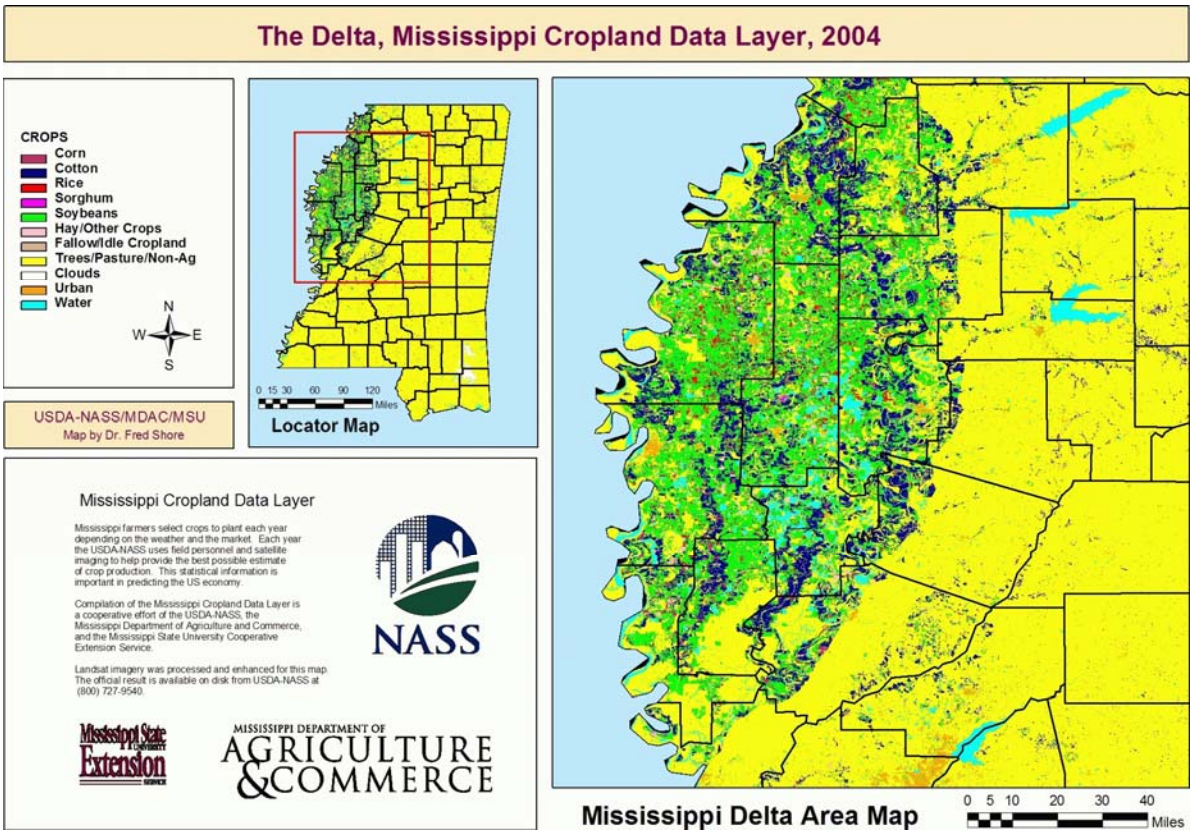

Figure 6. A presentation map of the Mississippi Delta, Cropland Data Layer, 2004.

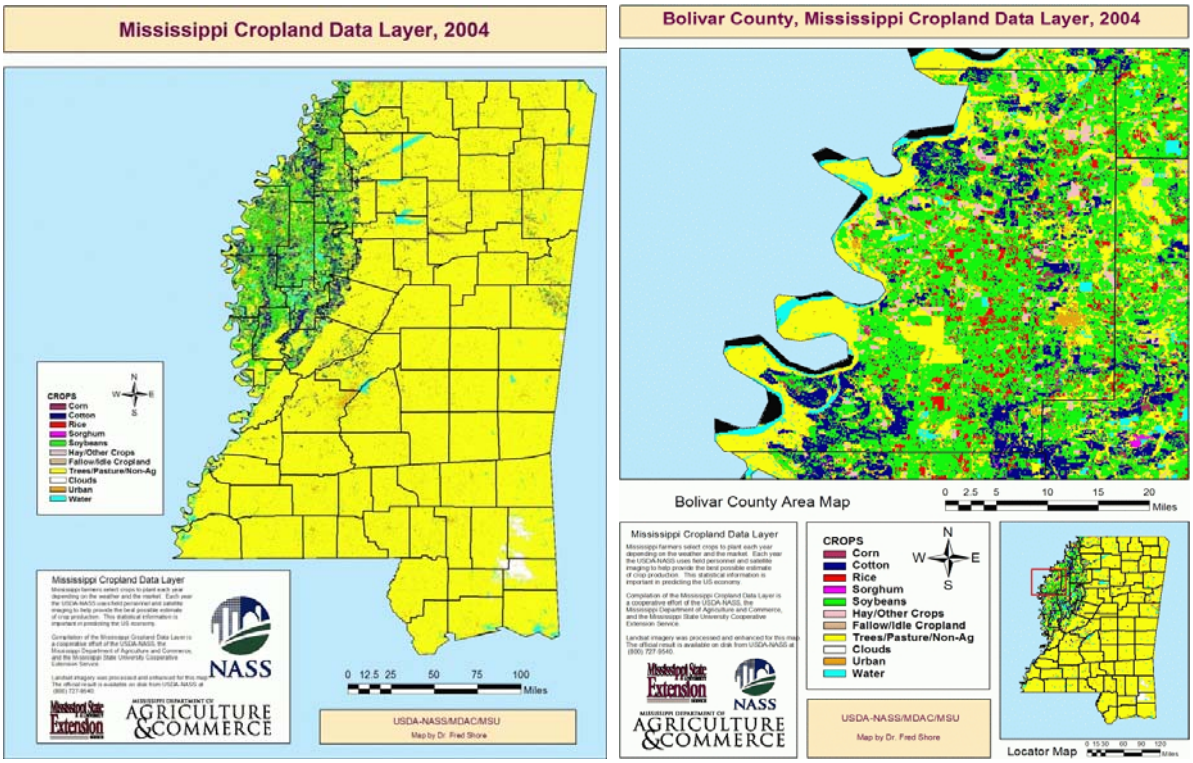

Figure 7. State and County Presentation Maps for the Mississippi Cropland Data Layer, 2004.

Figure 8. Multiyear overlays reveal more information about Mississippi agriculture than single year displays.

Crop Overlays by Priority

Overlaying soybeans with cotton and then overlaying both with rice reveals that potential rice acreage is nearly equivalent to the cotton acreage.

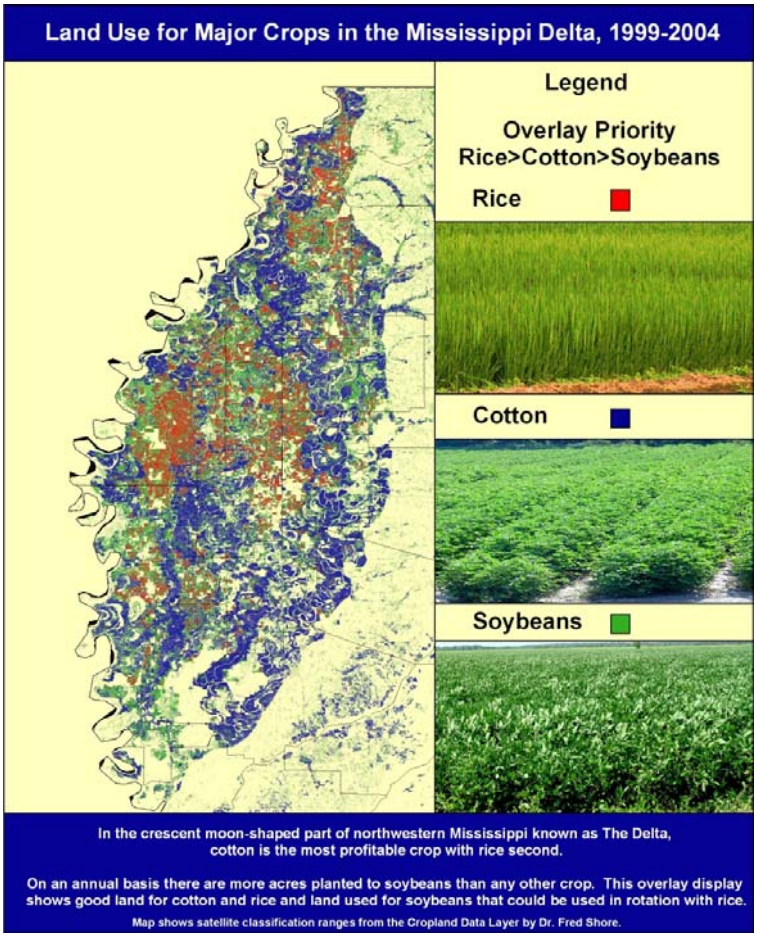

Figure 9. Land Use for Major Crops in the Mississippi Delta, 1999-2004. Sequential crop overlays reveal the relationship of land use for the major crops.

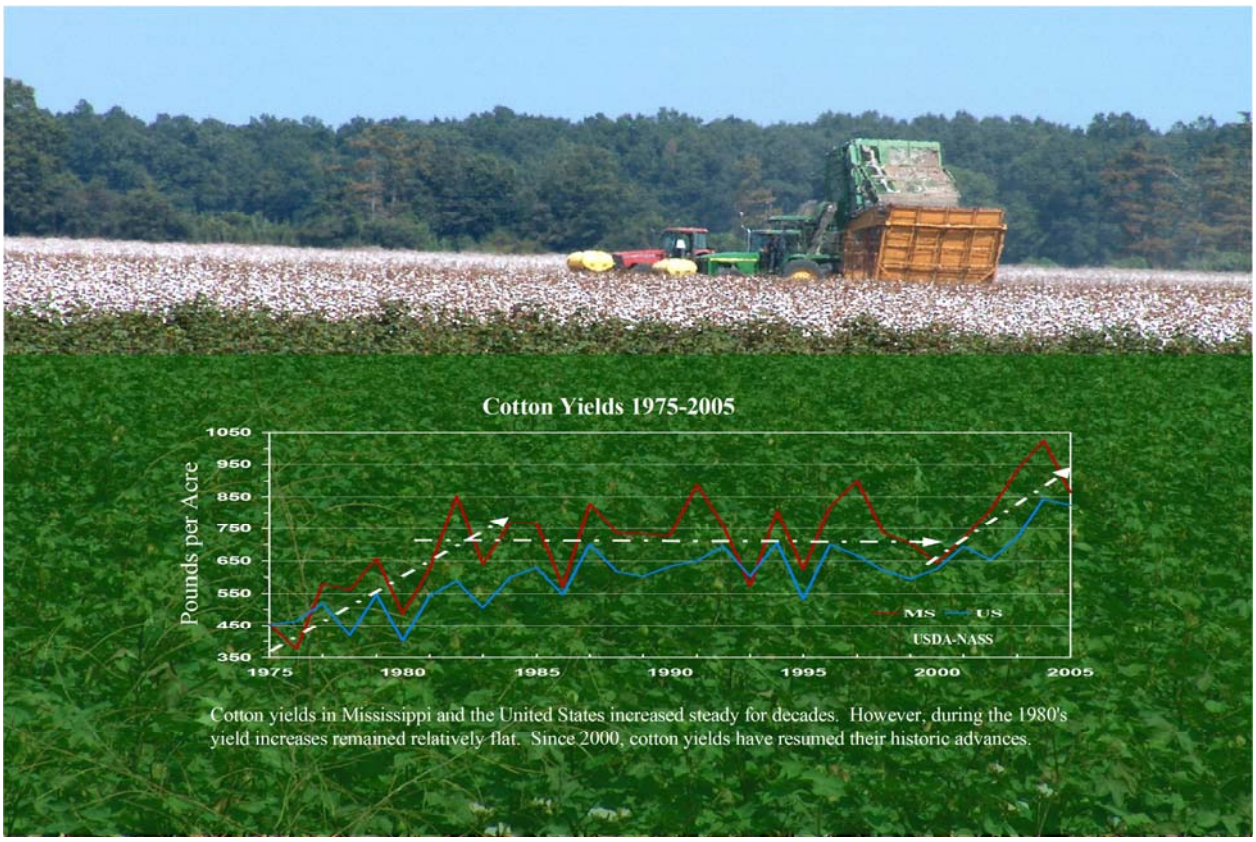

Figure 10. Cotton Yields 1975-2005. The use of ArcGIS allows direct printing of large format posters with graphical overlays to make statistics even more interesting.