A RESOURCE SHARING APPROACH TO CROP IDENTIFICATION AND ESTIMATION

Michael E. Craig
Senior Remote Sensing Analyst
National Agricultural Statistics Service, USDA
mcraig@nass.usda.gov

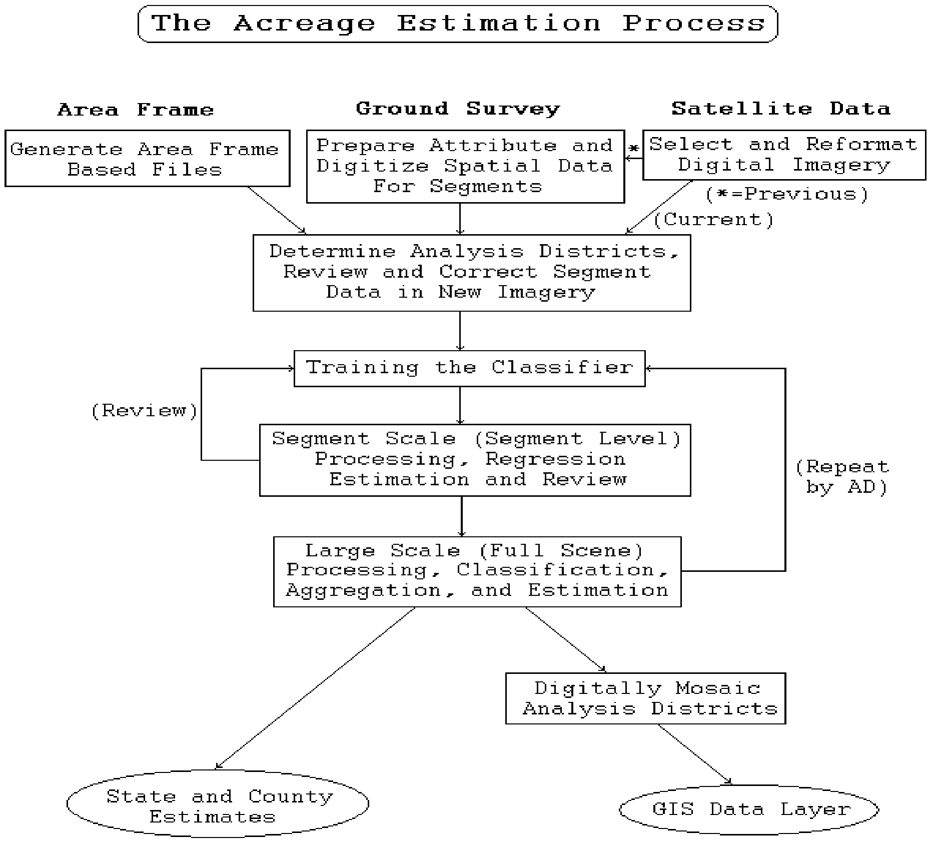
ABSTRACT

This paper presents a program based on agreements between federal agencies, state agencies, and university groups to use Landsat Thematic Mapper data for crop acreage estimation and identification. The resource sharing distributes the costs among the various groups allowing for program expansion. Ground truth data collection, Landsat V & VII satellite data acquisition, classifier training and cluster analysis, maximum likelihood classification for large areas, creation of GIS data layers, and the statistical estimation process are discussed. For the 2000 crop season, shared resource projects are underway in eight states: Iowa, Arkansas, Illinois, Mississippi, North Dakota, Indiana, New Mexico, and a pilot area in Florida. Products from this work come in two main forms: numerical crop acreage estimates and a digital crop specific GIS data layer. Numerical estimates of major crops are made at county and state levels and are delivered to National Agricultural Statistics Service (NASS) field offices in time to meet the NASS end-of-crop season time requirements. The digital data layer is produced in a common commercial GIS format and distributed via CD-ROM at no charge. Except for startup years, the CD-ROM will contain both the current year and the previous year classifications, attribute data with error rates, and an overview of the process.

INTRODUCTION

The following discussion covers the issues and challenges related to a multi-state project for identification and estimation of crop areas. Where this paper focuses on resources and how they were shared, a companion piece (Hanuschak, 2001) describing the economic cost of past and current remote sensing based crop acreage programs will be presented later this year at the CAESAR Conference in Rome, Italy. Methodology and resources used in the crop identification and estimation process in NASS are common to most remote sensing projects. The project phases are: ground data collection and digitization of boundaries, selection of current year satellite imagery, location and review of ground sampled areas in the selected current year imagery, training the classifier based on known sample information, evaluation of the classifier, full scene processing, acreage estimation, and creation of a GIS data layer. Figure 1 shows the NASS identification and estimation process in a flowchart. Image processing at NASS is performed on Windows NT workstations with the in-house developed PEDITOR software (Ozga, 1995). Some process details and highlights are: modified supervised clustering based on an updated ISODATA algorithm; classification based on a standard maximum likelihood algorithm; classifier evaluation based on percent correct, kappa coefficients, and regression analysis; crop acreage statistics based on regression and ratio estimators; categorized full scenes exported to ERDAS; and finally, full state mosaics (Mueller, 2000) produced using ERDAS and distributed on CD-ROM with the ESRI ArcExplorer viewer.

Resource costs include: direct costs such as hardware, software, and satellite imagery; staff resources for survey preparation, ground enumeration, digitization, image processing, statistical estimation, and GIS related tasks; and more indirect costs such as travel and training. The history of the NASS estimation approach is covered; identifying resources used and how they have changed during the period from the early 1970's through the mid 1990's. Three full state pilot projects in 1997 and 1998 were used to test an expert system approach to decentralization of staff workload. Methodology details derived from the 1997-98 pilot tests are discussed with respect to the present day project approach along with the phases of the expanded project started in 1999 regarding resource allocation and sharing among cooperating groups.
Figure 1:


The Acreage Estimation Process
Area Frame
Ground Survey
Satellite Data
Generate Area Frame Based Files
Prepare Attribute and Digitize Spatial Data For Segments
Select and Reformat Digital Imagery
(*=Previous)
(Current)
Determine Analysis Districts, Review and Correct Segment Data in New Imagery
Training the Classifier
(Review)
Segment Scale (Segment Level) Processing, Regression Estimation and Review
(Repeat by AD)
Large Scale (Full Scene) Processing, Classification, Aggregation, and Estimation
Digitally Mosaic Analysis Districts
State and County Estimates
GIS Data Layer

NASS HISTORY OF CROP ACREAGE AND REMOTE SENSING

The National Agricultural Statistics Service (NASS) began research into the possibilities of acreage estimation based on digital data from satellite multi-spectral sensors in the mid-1970's with the launch of Landsat I (Hanuschak, 1982). Before this, NASS estimation of crop acreage relied mainly on indications obtained from surveys of farmers, statistically selected from sample land areas or from lists of farm producers (Vogel, 1999). End of season estimates would be checked against administrative data obtained from other sources. Early research work looked at the possibility of reducing the number of farmer list or area sample contacts, or increasing the precision of the acreage estimates. Graphics from the early work were very limited and hard to come by, and thus were not considered to be viable output products. Almost all project related work was accomplished by highly trained research staff; the analysts were mathematical statisticians who had been trained in remote sensing principles and procedures or computer professionals with imagery analysis backgrounds. Since early imagery was provided to NASS through a National Aeronautics and Space Administration grant, research staff costs, including travel and training, plus computer processing costs were determining factors in the size of the first projects related to remote sensing.

A major part of early work was the development of computer systems, both hardware and software, for image processing and statistical estimation. Landsats I, II, and III carried only the Multi-Spectral Scanner (MSS) sensor, so the software developed for processing digital satellite data was originally based on MSS characteristics. Image processing was accomplished on combinations of main-frame computers, mini-computers, and supercomputers. The LARSYS software system from Purdue University's Laboratory for Applications of Remote Sensing was incorporated as the base for further development. From this, a modular package containing both image processing and statistical procedures, named EDITOR, was created jointly by NASS, USGS, and the Center for Advanced Computation at the University of Illinois. Hardware began with PDP main-frames for most processing and later with the ILLIAC and Cray supercomputers for large volume work. Mini-computers were added for digitization tasks in the early stages of the project. The first full state project, for estimation of corn and soybean planted acreage in Illinois, was processed based on 1975 Landsat MSS imagery. This project took over two years to complete; costs at this point still contained a heavy developmental portion.

The next major project, corn and soybean estimation for Iowa with 1978 Landsat imagery, was completed for the end-of-season estimation process in late December. This was considered the first operational (i.e. 'real time') application of remote sensing in NASS. The project expansion was aided greatly in 1980 by the USDA Secretary's Initiative on 'Agriculture and Resource Inventory Surveys Through Aerospace Remote Sensing' (AgRISTARS). By 1987, the project had grown to estimation of major crops in eight states based on Landsat MSS imagery (Allen, 1988). Numerical estimates were still the main product of the eight state project; some graphical output products were produced, mainly paper land cover maps. Although most processing was performed in headquarters by research staff, some field boundary digitization functions were transferred to state locations. At this point, the major project costs were still associated with staff years and computer processing. There were 10-12 staff years associated directly with the project, about half were cartographic support staff.

In the fall of 1987 however, several factors led to the demise of the 'operational' acreage estimation project. First and foremost, the collection of digital data from Landsat MSS scanners was being phased out in favor of the improved Landsat Thematic Mapper (TM) sensor (Harris, 1990). A second factor was that the budget for the 1988 fiscal year was especially tight, and cuts effected NASS research areas. Acreage estimation at NASS entered a research mode to investigate the application of the Landsat TM or the new SPOT MSS sensors to crop type classification. Pilot areas in four states, covering most major US crop types, were studied using both Landsat TM and Spot MSS digital data. The sensor research pilots began in Kansas in 1986, Michigan in 1987, plus Arkansas and Iowa in 1988 (Harris, 1989; Stup, 1991; Allen, 1990; Bellow, 1991b). Significant software development was needed to incorporate the use of Landsat TM, especially in multi-temporal form and the data from the SPOT sensor. At the same time the software was migrated, or ported, from IBM main frames to run on high end PC workstations under the DOS operating system. The new software system was renamed to be PEDITOR or portable-EDITOR. Almost all processing was done in headquarters for the sensor comparison research, including the software development. During the sensor research time period, the cartographic support group shrunk to one full time person and occasional part time help from another project area in NASS.

The next operational program, known as the Delta Project, started in 1991with full state major crop estimation for Arkansas and Mississippi based on Landsat TM (Bellow, 1992). The project was expanded to include Louisiana in 1992, and further expansion was planned (Graham, 1993). In 1991, Landsat TM cost $2500 per scene for US government users and was a major contributor to overall project cost. The cost attributable to computer processing shrank considerably with the incorporation of PC image processing and analysis. Budget problems in fiscal year 1993 forced a program cutback to one state, Arkansas; as there was no money for new imagery. In 1996, the project encompassed one state (Arkansas); but with the idea of cutting some staff analyst and training time by creating an expert software system that would allow contributions by administrative and enumerator personnel . Between 1993 and 1996 there were several small pilot projects, one or two TM scenes in size: mapping 1993 small grains acreage on several Indian reservations in Montana, spring wheat estimation in the Dakotas in 1994, small area estimation research in Arkansas 1995 with simulated high resolution sensors, and a pilot test for classification of California almonds in 1996. The capability to use digital data from the LISS scanners of the Indian Resource Satellites (IRS) was incorporated into the PEDITOR system during this period. The spring wheat pilot project in the Dakotas (Cook, 1996), although not significant with respect to numerical acreage estimates, led to the creation of crop specific theme maps as an output product due to requests for both paper and digital copies from several interested external customers.

Several factors influenced the acreage estimation program in late 1996 and early 1997. A change in US farm policy in 1996 led to a reduction in small area (county) administrative data on crop acreage and remote sensing was seen as a possible source of supplemental data. The external user response to the crop specific theme maps as output products increased the utility of classified satellite imagery versus it's use only as an input to numerical estimates. The expert system based on PEDITOR software was ready for testing. The major factor however, was an agreement reached between NASS and the Production Estimates and Crop Assessment Division (PECAD) of the USDA's Foreign Agriculture Service (FAS) to provide NASS with Landsat TM data from their current year's purchases. FAS and the USDA's Farm Service Agency (FSA) have long cooperated by sharing facilities and analysts for remote sensing processing and also by obtaining US and non-US imagery simultaneously in large volume purchases at reduced prices (Bethel, 1998). Licensing restrictions on Landsat data had prevented distribution of imagery outside of the FAS/FSA facilities and immediate staff before this time. New USDA wide licensing regulations (signed with satellite vendors in late 1998 and 1999) and the greatly reduced cost of Landsat data allowed expansion of the program using the expert system approach as discussed below.

AN EXPERT SYSTEMS APPROACH TO ACREAGE ESTIMATION

The acreage estimation program was expanded in 1997 to address state and county real time crop estimation in three states: Arkansas, North Dakota, and South Dakota. The first version of an expert system, known as the Remote Sensing Program (RSP), was distributed to these offices to allow them to manage ground truth data collection and digitize field boundaries. The original RSP system was built by combining DOS FoxPro task management procedures with initiation of appropriate PEDITOR modules, providing an event driven GUI interface that guided the end user. It allowed multiple users in the field office to simultaneously process system tasks. Training and documentation was provided to designated state office personnel (usually administrative or enumerator staff) in the ground data management and digitization/labeling procedures. Analysis and further image processing was accomplished in headquarters. The first mosaic combining all categorized scenes from one state together into a single digital image was produced for the three states and distributed on a limited basis within the research community. County and state crop estimates were created for the operational program in real time. Major project costs now are almost all staff related, with some initial hardware outlay.

The 1998 project remained at three states, and featured an improved Visual FoxPro based RSP expert system for the state offices. In headquarters, the next phase of the research began capturing and testing established 'rules of thumb' for image processing and programmed them into batch procedures for training (clustering) and testing of the classifier. PEDITOR was migrated from 16-bit to 32-bit processing, expanding many program arrays to handle the improved processing and data volume. The BATCH module was written as the next part of the expert system (Ozga, 2000). It incorporated the Windows NT console mode for batch initiation of large volume multi-task jobs and the NT environmental variables concept to pass information between programs and tasks. Computationally intensive jobs were linked/chained together to form the next part of the expert system**.** Preprocessing steps such as digital image capture for ground training were added or improved.

The combination of the RSP expert system and the BATCH module allowed expansion of the program to three states with less staff time required from the fixed pool of remote sensing analysts. A CD-ROM was created for each state, containing mosaics of both years in commercial Geographic Information Systems (GIS) vendor format and a freeware GIS viewer from ESRI called ArcExplorer. These CD's were prepared for general distribution to the public. As before, crop acreage estimates were generated in real time and distributed to the state offices for their use in county (and in some instances, state) crop acreage estimation.

A TASK BY TASK IDENTIFICATION OF RESOURCES

The following section describes the resources needed for the current approach in more detail versus their associated tasks. The major project tasks are: ground data collection and digitization of boundaries, selection of current year satellite imagery, location and review of ground sampled areas in the selected current year imagery, training the classifier based on known sample information, evaluation of the classifier, full scene processing, acreage estimation, and creation of a GIS data layer.

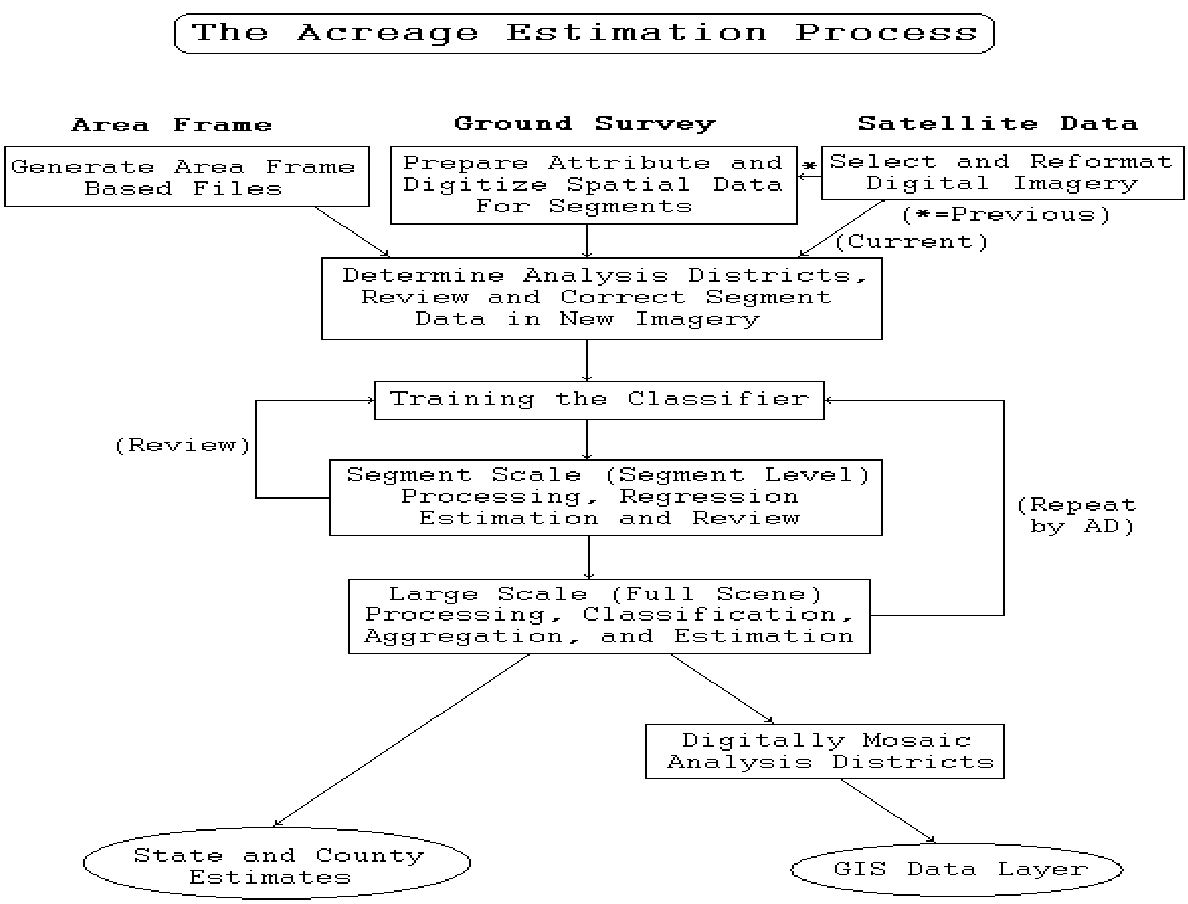
Ground survey preparation is the first task in the process. NASS has an existing nationwide survey program, called the June Agricultural Survey (JAS), that utilizes enumeration of sample land areas for crop estimation (Benz, 2000). The area sample is a stratified random sample of the entire state; the strata are based largely on percent cultivation. Every June more than 11,000 sample areas, known as segments and averaging approximately one square mile each, are visited and enumerated with respect to crop acreage. Sample areas are located based on county maps and black and white high resolution aerial photography. A bitmap image of the segment photo is captured for later reference. The perimeters of these segments (that are in included states) are digitized and geo-rectified on satellite imagery from previous years. The JAS master dataset of information about the individual segments must be populated into the RSP ground data management system. Resources for this task are almost completely staff related; cartographic technicians in NASS headquarters perform the outer boundary digitization, geo-rectification, and bitmap creation while a headquarters remote sensing analyst populates the database and prepares RSP's datasets for the the JAS process. Hardware and software costs are minimal and are absorbed into the normal headquarters overhead.

During the JAS ground data collection phase, segments are enumerated during personal contacts with farmers. It should be noted here that all farmer reported data is strictly confidential by law and is only available to NASS statisticians. Field boundaries are drawn on black and white aerial photography as a quality control measure. For segments in remote sensing project states, some special handling is required during the enumeration phase, mainly with respect to delineation of waste and wooded areas. Enumerators from the National Association of State Departments of Agriculture (NASDA) are trained for the JAS survey by NASS state office personnel and paid via a NASS contract with NASDA. A remote sensing coordinator is assigned by each state office and is responsible for management of the ground data collection and digitization. This coordinator and one or more assistants are trained in the state office by a NASS headquarters remote sensing analyst. Digitization of field boundaries is accomplished in the state office by administrative personnel and/or NASDA enumerators. Software at this point consists mainly of the RSP event driven expert system which executes several PEDITOR modules. RSP makes calls to PEDITOR for field digitization, field labelling, and ground truth checking against digitized fields. The RSP system automates the import of the field level data, such as farmer reported field size and crop or cover type, from the standard NASS survey editing system used by all states. Hardware costs are minimal and are absorbed into the normal state office overhead.

As discussed earlier, Landsat TM imagery is obtained through a cooperative agreement with the FAS/FSA headquarters unit named PECAD. NASS headquarters provides payment to PECAD to cover the cost of handling and overhead for their staff time. PECAD obtains any Landsat V imagery with less than 50 percent cloud cover for most of the world's major crop areas from Space Imaging Inc., and orders Landsat VII on request for specified areas from the USGS EROS Data Center and/or Radarsat International. NASS headquarters analysts review thumbnail images of the current year scenes available and select those images possibly useful for the project. Copies of the images selected are distributed to their respective state offices as they are obtained from PECAD. NASS remote sensing analyst staff time and minor materials costs are covered in the headquarters budget.

Location and review of sampled areas in the current years imagery starts with the reformatting (import) of selected imagery into PEDITOR format. Where available, multi-temporal (two date) imagery is created using an automated block correlation approach. The Windows NT based BATCH expert system module in PEDITOR automates scene reformat and multi-temporal image creation. Segment and internal field boundaries are overlaid on the new imagery, and any necessary local calibrations, known as segments shifts, are performed. Segments within each satellite scene are reviewed on a field by field basis to identify any 'bad' fields where the reported data does not match the information seen in the digital satellite imagery. This process includes such things as cropland already harvested, poor crop stands, cloud and haze affected areas, poorly drawn boundaries, and areas where the planted cover observed during enumeration does not match the farmer reported cover. Fields with problems that cannot be corrected are identified and later marked as 'bad for training'. Cloud affected segments are removed from consideration with respect to the specified scene. Analysis districts, which are unique areas covered by the same date of imagery, are defined during this process. These image processing steps require a trained remote sensing analyst. Computer processing at this stage requires at least one Windows NT workstation with several gigabytes of disk storage available. Software needs are still covered by the in-house PEDITOR and RSP systems.

Training the classifier based on known sample information is accomplished in an automated fashion by using the BATCH module. The NASS automated procedure uses a modified supervised approach in the creation of cover type signatures. In this approach interior (non-boundary) pixels from known fields, not labeled as bad for training, are sorted according to cover type into separate files. This procedure is known as packing. Using a principle components analysis, additional pixels are deleted ('clipped') from the files (Winings, 1990). Each updated file is then clustered, using a modified ISODATA algorithm which allows cluster splitting and merging (Bellow, 1991a). The resultant signature statistics for clusters from all cover types are then combined into one statistics file for input to the maximum likelihood classifier. All available known pixels from the sample segments are categorized using this classifier. A trained remote sensing analyst oversees the process. A dual processor Windows NT workstation is recommended for the BATCH training tasks. This workstation utilizes a commercial purchased scripting language name XLNT to allow job submission from other networked workstations.



Calculation of the statistics used for evaluation of the classifier is also performed by the BATCH module. Known pixels are tabulated comparing ground truth labels with the category assigned during classification. Percent correct, commission errors, and kappa coefficients are calculated automatically from the tabulation. Another module calculates regression coefficients at the segment level for reported versus categorized data at the segment level. A field by field analysis is also performed to check which signatures cause the most classification errors. A remote sensing analyst reviews these outputs and revises or restarts the BATCH process to produce a final statistics file for classification.

Full scene classification is a computationally intensive task that can be performed on the dual processor Windows NT workstation recommended above. This task is also executed by the BATCH module in an automated fashion. Only minimal interaction is needed by the remote sensing analyst except when there is a timing concern or a large number of scenes to process.

A new PEDITOR module named RESTP has been created to automate the acreage estimation functions. RESTP is the final addition to the expert system approach and is being tested with the crop year 2000 datasets. This module executes other PEDITOR modules in prescribed order to input both classified full scenes and ground truth information and output crop acreage estimates at state and county levels (Bellow, 1994a; Bellow, 1994b; Day, 2001; Graham, 1993). This module requires a Windows NT workstation although there are no substantial issues with processing speed or volume disk storage. A remote sensing analyst reviews the outputs on a step-by-step basis; some training in regression analysis is required.

The final process is the creation of a GIS data layer in a common commercial format. The PEDITOR system exports the individual full scene classifications in a format readable by the ERDAS Imagine package. A state level geo-rectified mosaic in ERDAS LAN format is then created using several ERDAS procedures. The current mosaic and a previous year mosaic (if available) are copied to a CD-ROM along with attribute data showing classification error analysis and methodology. The ArcExplorer freeware viewer, developed by ESRI, is included on the CD-ROM. Copies of the CD-ROMs can be obtained free from the NASS website for included states. The Appendix contains images of four counties classified during the 1999 project: Craighead, Arkansas; Bolivar, Mississippi; Cass, North Dakota; and McLean, Illinois. For further information on the project, you can contact the USDA, National Agricultural Statistics Service, Spatial Analysis Research Section through their web page at: http://www.nass.usda.gov/research/SARS1.htm.

RESOURCE SHARING PARTNERSHIPS

After the 1998 crop season, a review of the project procedures, resource needs, and costs led to the conclusion that even with the above mentioned efficiency increases and improved products, the project could not continue to expand without the addition of outside resources. In the fall of 1998, State Statisticians in NASS field offices were tasked with investigating additional Federal, State, University, or other outside partners to share resources and outputs from the remote sensing acreage program. Under the expansion plan, and in addition to their normal June Survey data collection, each state needed a project coordinator for ground data processing, a remote sensing analyst, and additional hardware (a dual processor Windows NT workstation and a imagery capable color printer). Project coordination, troubleshooting, PEDITOR software, and satellite imagery (obtained from FAS/FSA) would be provided by NASS headquarters. Except for some survey preparation tasks performed in NASS headquarters, all other work up to and including the full scene classification would be performed in the state offices, while the final estimation and state mosaic creation would be performed in NASS headquarters.

Based on these investigations and on prior working relationships, five states were chosen for the 1999 project: Arkansas, Illinois, Mississippi, New Mexico, and North Dakota. Two of these states, Arkansas and North Dakota, did not have a new partnership plan in place for 1999. North Dakota had several possible partnerships but none could commit before 2000. Although they did not have any new resources, Arkansas stayed in the program because they were the first test state for the expert approach and the staff were already trained, their rice estimate was important nationally, and only a small volume (approximately one-half of the other states) of processing work was needed. The other three states found different sources or partnerships for resource sharing.

In NASS headquarters a training plan was developed for the five states. A ground survey coordinator had to be trained in the use of the RSP expert system and related PEDITOR modules. Additional assistants in each state would be trained at the same time as the coordinator (or at a later time by the coordinator) in boundary digitization tasks. A headquarters analyst traveled to each state before the June Survey enumeration period to install the RSP and PEDITOR plus give a three day coordinator training workshop on-site. Coordinators were usually state administrative staff or supervisory enumerators who understood the operational June Survey effort. The training covered rudimentary remote sensing and cartographic principles and the use of the RSP system for on-screen PC-based digitization. Staff costs for the survey data collection and the ground data coordinator were covered by NASS through the state office overhead (for administrative staff) and/or through their agreement with NASDA (for enumerator work).

By the fall of 1999 the state based remote sensing analysts were in place for Illinois, Mississippi, and New Mexico. A nine day training workshop on PEDITOR software was planned for the new analysts and for a staff member from North Dakota. The PEDITOR training assumes a basic knowledge of remote sensing terms and definitions and a rudimentary introduction into image processing. Since one of the analysts background was purely in data processing, an introduction to remote sensing 'course' was designed that utilized a combination of a NASA Online Tutorial (Short, 1997) and a Canadian Center for Remote Sensing (CCRS) image processing course (Alfoldi, 1978). The PEDITOR training workshop was held in NASS headquarters in late October and early November, 1999.

The Illinois analyst was funded through the NASS state office's partnership with two Illinois state agencies: the Department of Agriculture and the Department of Natural Resources. This analyst had a background in geography, remote sensing, and agronomy. The state agencies also purchased a high-end dual processor Windows NT workstation and a color printer for the project.

The New Mexico analyst was jointly funded through a two year Memorandum of Understanding between the NASS field office, the USDA's National Resource Conservation Service's field office, and the NM state governments' La Union Soil and Water Conservation District. The NM analyst has a background in agriculture, applied geography and city/regional planning and would work for this project on a half time basis for the two years. His computer hardware was donated by the La Union Soil and Water Conservation District.

In Mississippi, a partnership was formed via a cooperative agreement between NASS, the Mississippi Department of Agriculture (MS DoA), and the Extension Service of the Mississippi State University (MSU). The analyst was funded by the MS DoA. His background was mainly in automated data processing and although he had an interest in remote sensing and GIS he had no prior formal training in these areas. The MSU Extension Service purchased the high-end dual processor Windows NT workstation and a color printer for the project.

For crop year 2000, two more full states (Indiana and Iowa) and a pilot region in Florida were added to the project. In addition, a partnership for the North Dakota part of the program was finalized. The Arkansas office was unable to find an official partner, but decided to continue the project by assuming the remote sensing analyst duties in the state office operational program overhead. Dual processor Windows NT workstations from headquarters were donated to North Dakota and Arkansas for 2000 since their partnerships were not in place. Florida A&M University and NASS entered into a cooperative program for minority student outreach in remote sensing and GIS by analyzing a portion of northern Florida with student observed fields rather than use NASS's June Survey data, as the focus of this project is land cover mapping rather than acreage estimation.

Indiana was added to the project as a test of a regional analysis concept to explore processing efficiencies in adjoining major crops states. Although the Indiana field office would perform the ground data related tasks, the remote sensing and image processing tasks were assigned to the analyst in Illinois. The PEDITOR software system was revised to allow classifier training and signature development across state lines. Around the same time, the Illinois analyst position was converted to a federal NASS position but funded by the partnership with Illinois Department of Agriculture and Department of Natural Resources.

The North Dakota partnership was funded as part of a five year US Environmental Protection Agency grant given to the North Dakota Department of Health for ‘Satellite Imagery Applications to Water Quality’. The North Dakota State University Extension Service’s Agriculture and Biosystem Engineering unit will oversee the work and act as the official partner. The analyst hired under this agreement has formal training in agriculture, natural resources management, and geographic information systems.

The addition of Iowa comes through a Memorandum of Understanding between NASS and the Iowa State University. Under this agreement, Iowa State will provide hardware and a remote sensing trained graduate student for analyst support. The rotation of graduate students and the training implications thereof for NASS are a concern at this time.

For the 2000 project, the training needs were similar to that given in 1999. The Illinois analyst set up RSP and PEDITOR in Indiana and trained the Indiana coordinator on-site prior to the June Survey enumeration period. A NASS headquarters analyst did the same for the Iowa state office. A nine day PEDITOR workshop was held in NASS headquarters for the remote sensing analysts from North Dakota, Iowa, and Florida A&M.

SUMMARY AND FUTURE PLANS

In the technical sense, results from the acreage identification and estimation program are generally quite good, but may vary from year to year due to the cloud cover problems associated with the 8 day repeat coverage when two Landsat satellites are available. The cloud cover problem will increase significantly when only one satellite is available. On the software side, once the RESTP module is fully tested and implemented, the estimation task will be performed in the state offices. A two day self taught workshop on estimation is also being tested. Initial development and testing are underway using PEDITOR rather than ERDAS as a solution to the mosaic process that can then be migrated to the states also.

In the personnel sense, NASS started with a small group of expert analysts in its’ Research Division who were performing centralized analysis for several States. However, it was recognized that a decentralized analysis staff directly in NASS State Statistical offices would expand the Agency’s analytical capabilities. In addition the analyst will have the advantage of more localized knowledge of the crops and cropping practices and other sources of data to evaluate the relative contribution of the Landsat to the NASS crop area estimation program at the State and county level. A local analyst and State office management will also be in a better position to service other State governments, universities, farm organizations and agribusinesses by providing them a Cropland Data Layer in common commercially available geographic information system (GIS) format.

NASS will continue to pursue partnerships, primarily with State governments, to expand the crop area estimation and Cropland Data Layer program to more States. The desires are for program expansion to the top 20 total cropland States in the United States. Expansion beyond that point is unlikely. The value of the Cropland Data Layer to the general public is hard to quantify but is considered substantial to those GIS data users who combine it with other data layers to solve their problems of interest.

REFERENCES

Alfoldi, T. (1978). Introduction to Digital Images and Digital Analysis Techniques: A basic Course for the Appreciation of Digital Analysis of Remotely Sensed Multispectral Data. Technical Note 78-1, Canada Center for Remote Sensing, Natural Resources Canada, Ottawa, Canada.

Allen, J., and Hanuschak, G. (1988). The Remote Sensing Applications Program of the National Agricultural Statistics Service: 1980-1987. SRB Staff Report Number SRB-88-08, USDA, National Agricultural Statistics Service, Washington, DC-USA.

Allen, J. (1990). Remote Sensor Comparison for Crop Area Estimation Using Multitemporal Data. SRB Staff Report Number SRB-90-03, USDA, National Agricultural Statistics Service, Washington, DC-USA.

Bellow, M., and Ozga, M. (1991a). Evaluation of Clustering Techniques for Crop Area Estimation Using Remotely

Sensed Data. In: *1991 Proceedings of the Section on Survey Research Methods*, American Statistical Association, Atlanta, GA-USA, pp. 466-471.
Bellow, M. (1991b). Comparison of Sensors for Corn and Soybean Planted Area Estimation. SRB Research Report Number SRB-91-02, USDA, National Agricultural Statistics Service, Washington, DC-USA.
Bellow, M. and Graham, M. (1992). Improved Crop Area Estimation in the Mississippi Delta Region Using Landsat TM Data. In: *Proceedings of ASPRS/ACSM/RT'92 Convention*, Washington, D.C., pp. 423-432.
Bellow, M. (1994a). Application of Satellite Data to Crop Area Estimation at the County Level. NASS Research Report Number STB-94-02, USDA, National Agricultural Statistics Service, Washington, DC-USA.
Bellow, M. (1994b). Large Domain Satellite Based Estimators of Crop Planted Area. In: *1994 Proceedings of the Section on Survey Research Methods*, August, 1994, American Statistical Association, Toronto, Canada, pp.194-199.
Benz, S. (2000). Area Frame Design Information - 2000 Edition. Internal document: USDA, National Agricultural Statistics Service, Area Frame Section, Washington, DC-USA.
Bethel, G. and Doorn, B. (1998). USDA Remote Sensing Technical and Systems Support for Operational Worldwide Agruiculture Analysis. In: *Proceedings of the 1st International Conference: Geospatial Information in Agriculture and Forestry*, ERIM International Inc., Ann Arbor, MI-USA, pp. 44-51.
Cook, P., Mueller, R., and Doraiswamy, P. (1996). Southeastern North Dakota Landsat TM Crop Mapping Project. In: *1996 ASPRS/ACSM Annual Convention Technical Papers*, Vol. 1, Baltimore, MD-USA, pp. 600-614.
Day, C. (2001). A Compilation of PEDITOR Estimation Formulas. RDD Research Paper RDD-01-01, USDA, National Agricultural Statistics Service, Washington, DC-USA.
Graham, M. (1993). State Level Crop Area Estimation Using Satellite Data in a Regression Estimator. In: *Survey Methods for Businesses, Farms, and Institutions*, ICES Part I, NASS Research Report No. SRB-93-10, USDA, Washington, DC-USA, pp. 7-11.
Hanuschak, G., Allen, R., and Wigton, W. (1982). Integration of Landsat Data Into The Crop Estimation Program of USDA's Statistical Reporting Service. In: *Proceedings of the 1982 Machine Processing of Remotely Sensed Data Symposium*, Eighth International Symposium, LARS, Purdue University, West Lafayette, IN-USA, pp. 45-56.
Hanuschak, G., Hale, R., Craig, M., Mueller, R., and Hart, G. (2001). The New Economics of Remote Sensing for Agricultural Statistics in the United States. To be included in the: *Proceedings of the CAESAR Conference, June 2001*, Italian Statistics Agency (ISTAT), Rome, Italy
Harris, J., Winings, S., and Saffell, M. (1989). Remote Sensor Comparison for Crop Area Estimation. In: *Proceedings of the IGARSS '89 Symposium*, Vancouver, Canada, Vol. 3, pp. 1860-1863.
Harris, J. (1990). The Comparison of Emulated Multispectral Scanner Data Sets. SRB Staff Report Number SRB-90-10, USDA, National Agricultural Statistics Service, Washington, DC-USA.
Mueller, R. (2000). Categorized Mosaicked Imagery from the National Agricultural Statistics Service Crop Acreage Estimation Program. Available on the CD: *Proceedings of the ASPRS 2000 Conference*, ASPRS, Bethesda, MD-USA.
Ozga, M., and Craig, M. (1995). PEDITOR - Statistical Image Analysis for Agriculture. Presentation at the Washington Statistical Society (WSS) Seminar, April, 1995, USDA, National Agricultural Statistics Service, Washington, DC-USA.
Ozga, M. (2000). Batch Processing of Remote Sensing Jobs on the PC. Available on the CD: *Proceedings of the ASPRS 2000 Conference*, ASPRS, Bethesda, MD-USA.
Short, N. (1997) The Remote Sensing Tutorial: An Online Handbook. On CD: NASA, Goddard Space Flight Center, Applied Information Science Branch, Greenbelt, MD-USA. Online: http://rst.gsfc.nasa.gov.
Stup, C., and Allen, J. (1991). The Construction of a Dry Bean Area Sampling Frame in Michigan. In: *Michigan Dry Bean Digest*, Vol. 15, No. 4, pp. 8-12.
Vogel, F., and Bange, G. (1999). Understanding USDA Crop Forecasts. In: NASS/WAOB Miscellaneous Publication No. 1554, U.S. Department of Agriculture, Washington DC-USA.
Winings, S., Ozga, M., and Stakenborg, J. (1990). The Effects of the Applications of Smoothing and Orthogonal Transforms to SPOT and TM Data on Regression Based Crop Acreage Estimates. In: *Proceedings of the IGARSS '90 Symposium*, College Park, MD-USA, Vol. 1, pp. 647-650.

APPENDIX

Following are four categorized county images taken from the 1999 acreage estimation project:

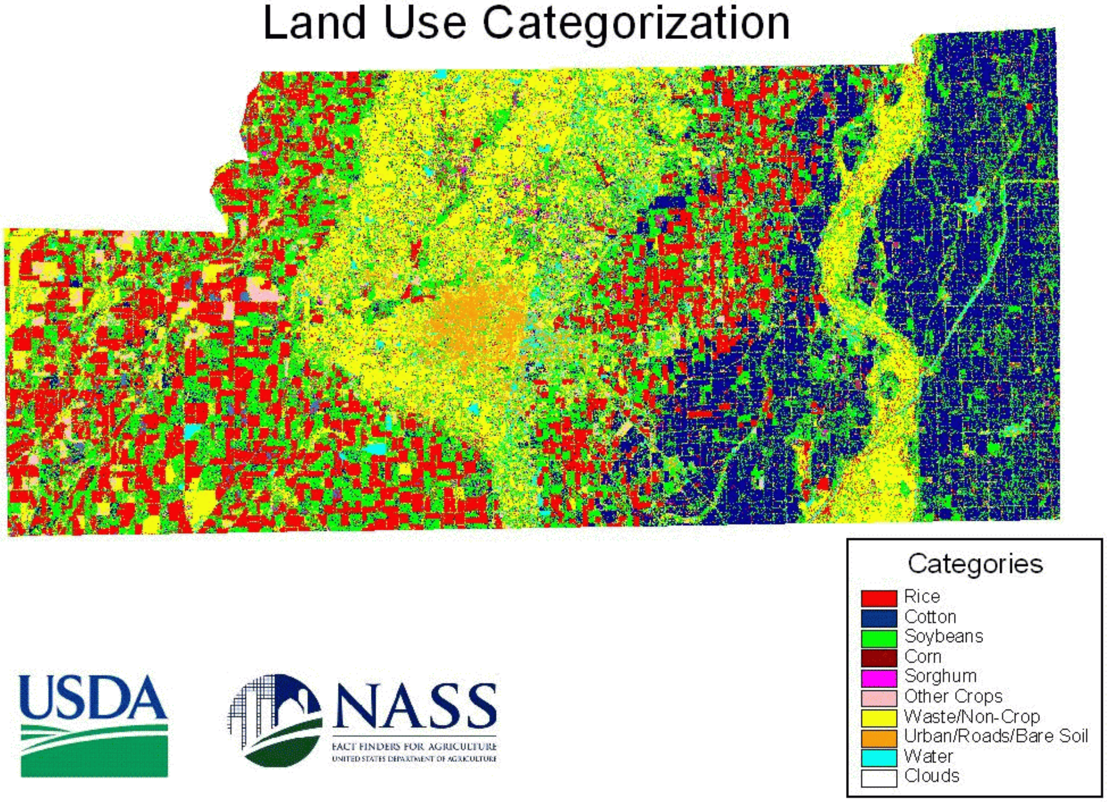
1) Craighead County, Arkansas: The county was split into east and west parts by imagery dates of August 12 and 13, 1999 (both were unitemporal analyses).

2) Bolivar County, Mississippi: The county was split into north and south parts by imagery dates of May 9 plus July 28, 1999 versus May 9 plus August 21, 1999 (two multitemporal analysis districts).

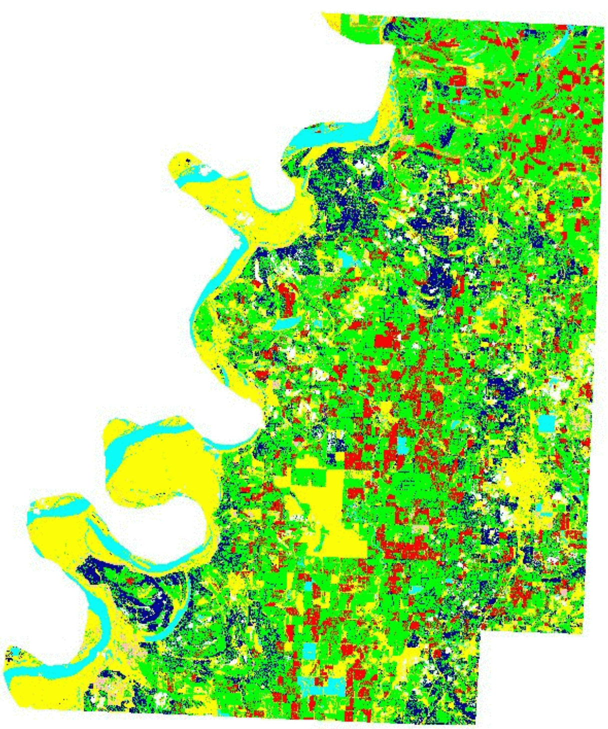
3) Cass County, North Dakota: The county was wholly contained in one multitemporal analysis district with imagery of May 26 plus July 29, 1999.

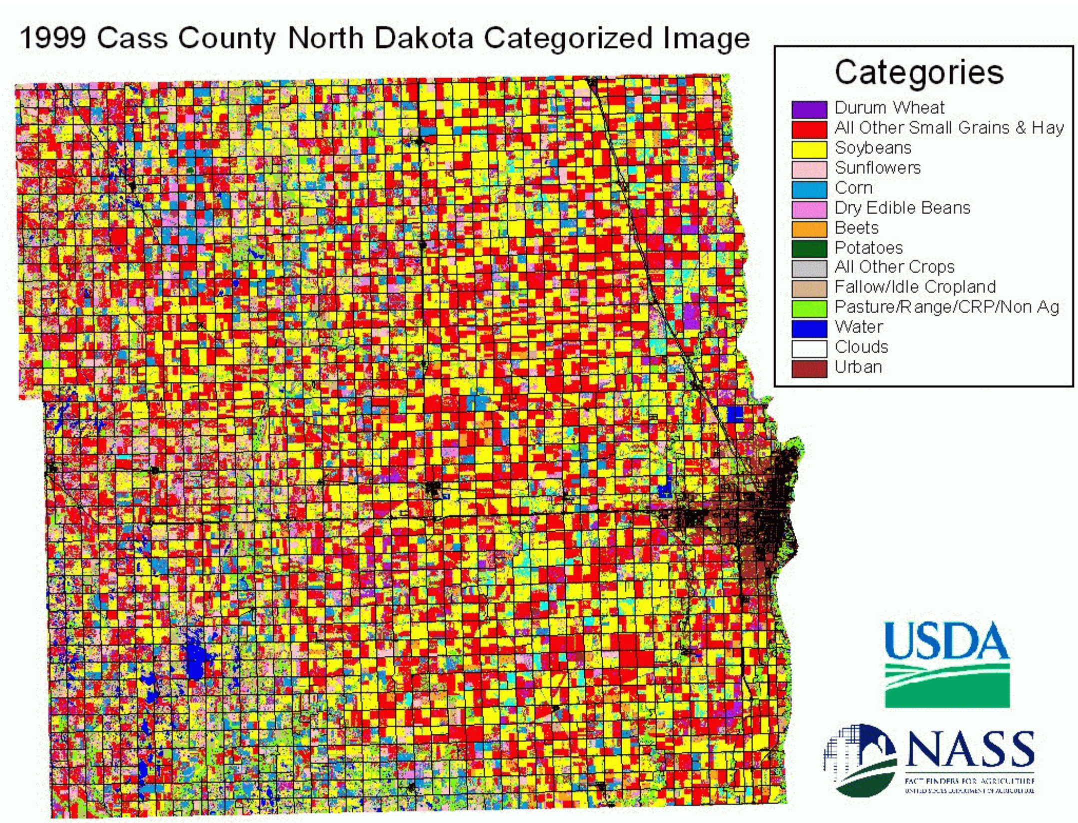
4) McLean County, Illinois: The county was wholly contained in one multitemporal analysis district with imagery of April 4 plus September 6, 1999.

1999 Craighead County Arkansas Land Use Categorization

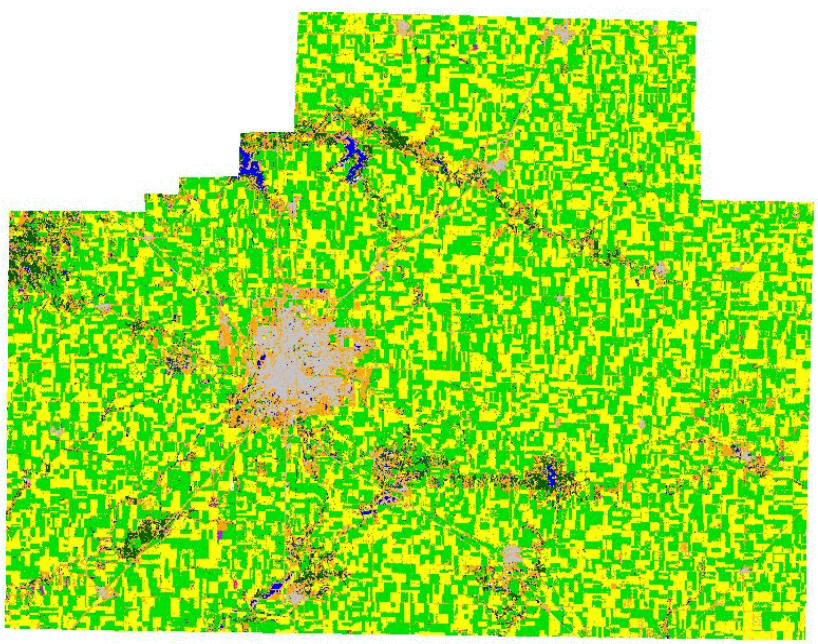


1999 Bolivar County Mississippi Categorized Image




1999 Cass County North Dakota Categorized Image
Categories
Durum Wheat
All Other Small Grains & Hay
Soybeans
Sunflowers
Corn
Dry Edible Beans
Beets
Potatoes
All Other Crops
Fallow/Idle Cropland
Pasture/Range/CRP/Non Ag
Water
Clouds
Urban
USDA
NASS

1999 McLean County Illinois Categorized Image



Categories
- Corn
- Soybeans
- Other Crops
- Winter Wheat
- Other Small Grains
- Idle Cropland
- Pasture/Non Ag/CRP
- Woods
- Water
- Urban
- Clouds

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