DETECTING AGRICULTURAL CHANGE USING HISTORICAL IMAGERY

Louise Mathews, Cartographer/GIS Specialist
USDA-FSA-Aerial Photography Field Office
Salt Lake City, UT 84119
louise.mathews@slc.usda.gov

ABSTRACT

Displaying and analyzing changes and trends in agriculture over time is becoming a more important topic of conversation from the aspects of agricultural production, increasing urban footprints, changes in farming practices, and general planning activities. Detecting change in agriculture over time requires historical data, such as imagery, or potentially vector based historical information. The USDA Farm Service Agency (FSA) Aerial Photography Field Office (APFO) has a massive archive of historical imagery reaching back to the 1950s. This paper will focus on what can or cannot be done, using automated and manual processes, in comparing multiple years of imagery (black and white, natural color, color-infrared, and multi-spectral) to detect agricultural change.

INTRODUCTION

Over the past year, the Geospatial Services Branch at the Aerial Photography Field Office (APFO) in Salt Lake City has addressed the topic of using geospatial data to show how agricultural land has changed over time. The office houses one of the largest collections of historical aerial photography in the country, as well as one of the largest collections of current digital aerial imagery. The studies have addressed several topics, using different methodologies, with the goal of understanding what sort of analysis is possible with our resources and skills.

THE AERIAL PHOTOGRAPHY FIELD OFFICE'S ROLE IN IMAGERY ACQUISITION

USDA's FSA has been administering the National Agriculture Imagery Program (NAIP) through APFO since 2003. The program was started to assist County Service Centers around the country in using GIS to help administer farm programs, but the imagery has been used extensively by other customers, public and private. The NAIP program provides a base layer of digital aerial imagery for use with vector files, digitized from the imagery, depicting farm fields. In earlier years APFO provided rectified 24" x 24" enlargements of aerial photography, on which the field boundaries were hand drawn.

FSA offices and APFO have turned their attention to digital aerial imagery, but 55 years of historical records remain in the film library. For centuries humans have relied on two dimensional depictions of the world around them. Elevation data, such as DEMs, have added the third dimension, to make depictions of the earth appear closer to the actual contours. The fourth dimension to add is temporal, and this is where APFO is capable of providing a unique and valuable service to the geospatial community, through its collections of historical film-based photography and digital imagery.

The film records at APFO date from 1955 – earlier imagery was sent to the National Archives. Most of the photography was flown for the Farm Service Agency or its predecessors, but some was flown for the Forest Service, or other agencies. Throughout the nation, a given county may have from 1 to 20 years of photography available, with the heaviest concentration of flying being for Midwestern counties. Beginning in 1980, USDA was part of collaborative flying programs administered by the U.S. Geological Survey (USGS). The National High Altitude Photography (NHAP) program ran from 1980 – 1989, and the National Aerial Photography Program from 1987 – 2003. These were flown at higher altitudes than the older ASCS imagery, on 5 – 7 year cycles, and the exposure stations were located on the centers of the Quarter Quads, or on the boundary between two quarter quads. Photography from the NAPP program was used by USGS to produce Digital Ortho Quarter Quads.

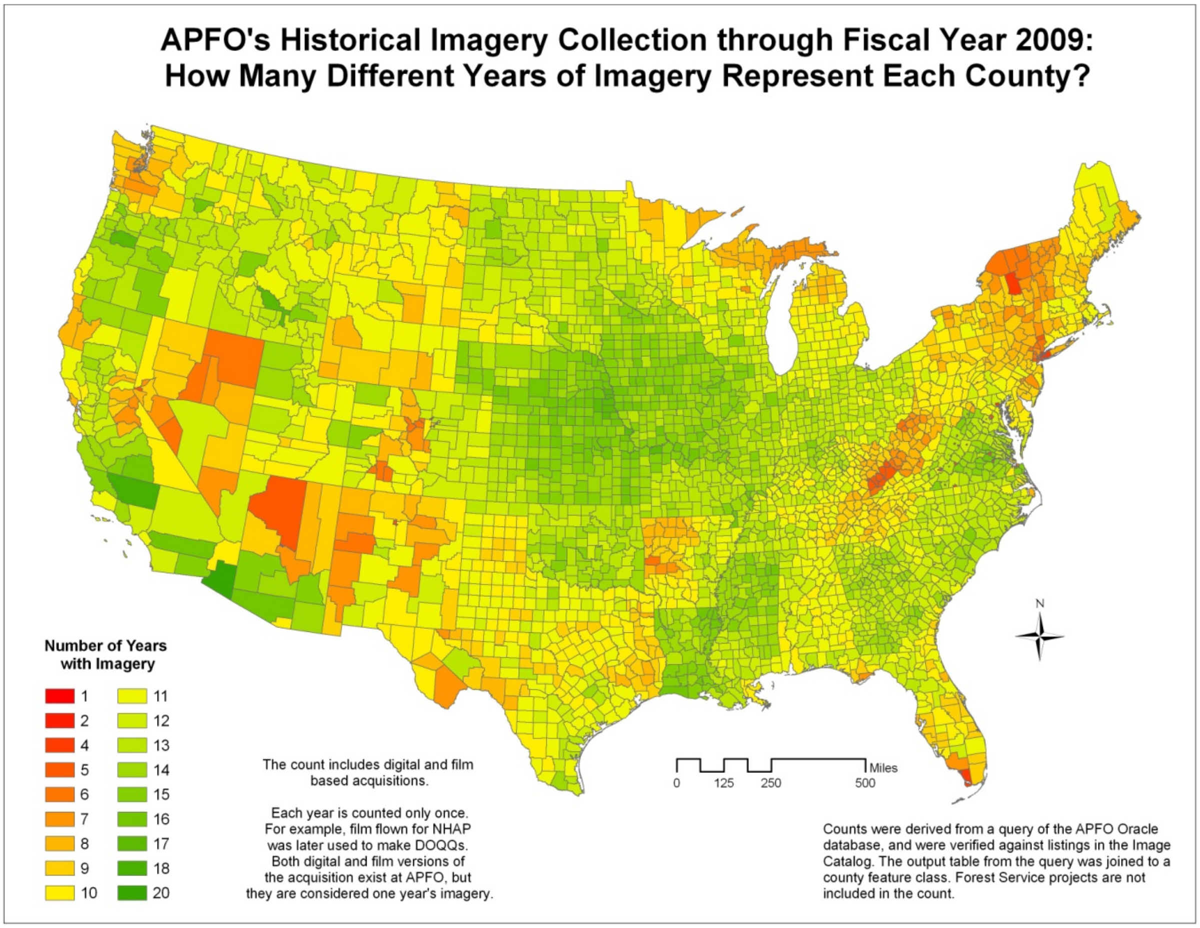


Figure 1. Distribution of aerial photography and digital imagery available at APFO for the conterminous U.S.

In the late 1990s, APFO began creating "seamless" mosaics from the DOQQs, in a full quad format called Mosaicked Digital Ortho Quads (MDOQs). MDOQs, rather than photo enlargements, were used in USDA service centers as a base layer for the implementation of GIS projects to be used in managing farm programs. Another new geospatial collection was created from the MDOQs. These were the Common Land Unit (CLU) shapefiles, which were polygons delineating the boundaries of farm fields enrolled in Federal programs; they were digitized based on the field boundaries hand drawn on the 24" x 24" photo enlargements. At present, CLU files are not available for use outside of USDA agencies. In 2003, FSA began the NAIP program to provide updated base layers for the GIS projects. In the past few years, many states have received four band imagery – red, green, blue and near infrared. Four band imagery opens more possibilities for automated analysis of agricultural change.

ORGANIZING A CHANGE ANALYSIS PROJECT

The first step in creating a change analysis study was organizing the raw materials. Small areas of interest were selected in different parts of the country, and exposures covering these areas from different years were identified. The film was scanned at 25 microns, yielding ground sample distances of 0.5 meters for photography flown at a 1:20,000 scale, 1 meter for 1:40,000 scale, and 1.5 meters for 1:60,000 scale. The exposures were georeferenced using ArcMap or ERDAS Imagine, with NAIP, MDOQs or Digital raster Graphics (DRGs) for the areas as source data. The scanned and georeferenced exposures were used to create mosaics for the study areas. The existing CLU files could be overlaid on the mosaics to see what today's farm fields looked like years ago.

The next part of the project was to locate or create ancillary files to be used with the scanned and geo-referenced imagery. This was more problematic, as historical CLU files do not exist. Historical photo enlargements with hand drawn field boundaries have also disappeared from the record. For most of the projects, manual digitizing was used to create historical field boundaries from the georeferenced images. Without knowledge of the crops grown in an area, or the ability to ground truth the fields, the digitizing was limited to generalized categories. Some crops, such as rice in California or shade tobacco in the Connecticut River Valley, can be more easily identified on earlier photography, but the contents of other farm fields is uncertain. It is possible to clearly see changes in more generalized classifications – such as changes from agricultural to urban land use, or the replacement of farms and woodlands with golf courses.

In one project area, historical boundary maps of the city were scanned and georeferenced, then used to manually digitize the city limits, which had expanded outwards over time. If this sort of historical map record is not available, vector files displaying temporal information cannot be accurately created.

Another source of ancillary data could be found in some of FSA's tabular records. The farm records are submitted by the producers, and can be joined to CLUs through the CLU ID field. These files have not been spatially enabled, but doing so could increase their value in FSA programs. Text files of data from the Conservation Reserve Program (CRP) are often included with the CLU, and can be joined to them. Of course, this would have little use in a temporal analysis, since only the most recent versions are retained.

ANALYZING HISTORICAL DATA

When doing a historical agricultural analysis, a basic hypothesis needed to be developed. Since we were just beginning to explore this avenue of research, we started with the most basic question: How much agricultural land was lost to development? Using the tools at hand, the analysis could move from looking at (1) a single image to (2) comparing imagery from different dates to (3) comparing imagery with vector layer information.

With black and white photography, automated methods of classifying imagery are severely limited, and are dependent upon the software available at APFO and the knowledge of those using the photography. A few years of NHAP and NAPP photography were flown with CIR, which could be more useful in automated classification. However, these projects were usually flown "leaf off," and did not give the sort of usable agricultural information that would be found during the growing season. In addition, the exposures for a given county were not always flown at the same time; the checkerboard of image dates and different spectral signatures for the same types of fields diminished the photography's value for automated agricultural analysis.

Analyzing a Single Image

When looking at a single image from any given year, the user can derive basic information about land cover, such as the ratio of impervious surfaces to vegetation; vegetation could be further classified as forested versus open fields. These categories can be further divided by things such as tree or crop type, or into land use classifications such as recreational, crops, fallow fields, or landscaping.

Comparing Imagery to Imagery

In comparing imagery to imagery, the most basic information is determining areas of change. This is an area where automated classification methods might be useful, especially when used with imagery containing an infrared band. A study was done using Texture Analysis with Unsupervised Classification in ERDAS Imagine to create a map of "Agricultural Likelihood" between 1958 and 2008, mapped on a scale from 1 to 10. (See Appendix 1)It correctly identified 85% of the agricultural lands which had remained unchanged since 1958. The pixels had been resampled from 1 meter to 10 meters, and the analyst stated that a good deal of manual editing still needed to be done in creating a final output. Another study used the Normalized Difference Vegetation Index (NDVI) tool in Imagine to isolate areas of impervious surface. The output raster file could then be overlaid with a manually digitized file based on historical imagery to easily locate areas of change.

However, in most of the studies, automated classification methods were not used because:

- Manual digitizing was quicker and more accurate in a small area
- Most historical imagery was one band (black and white)
- Historical photography with three bands often had different flying dates, producing differences in spectral signatures.
- Three band historical imagery was usually flown "leaf off", and was less valuable for agricultural analysis
- The georeferenced images often had offset – within a single mosaic of images, and between different years of imagery.

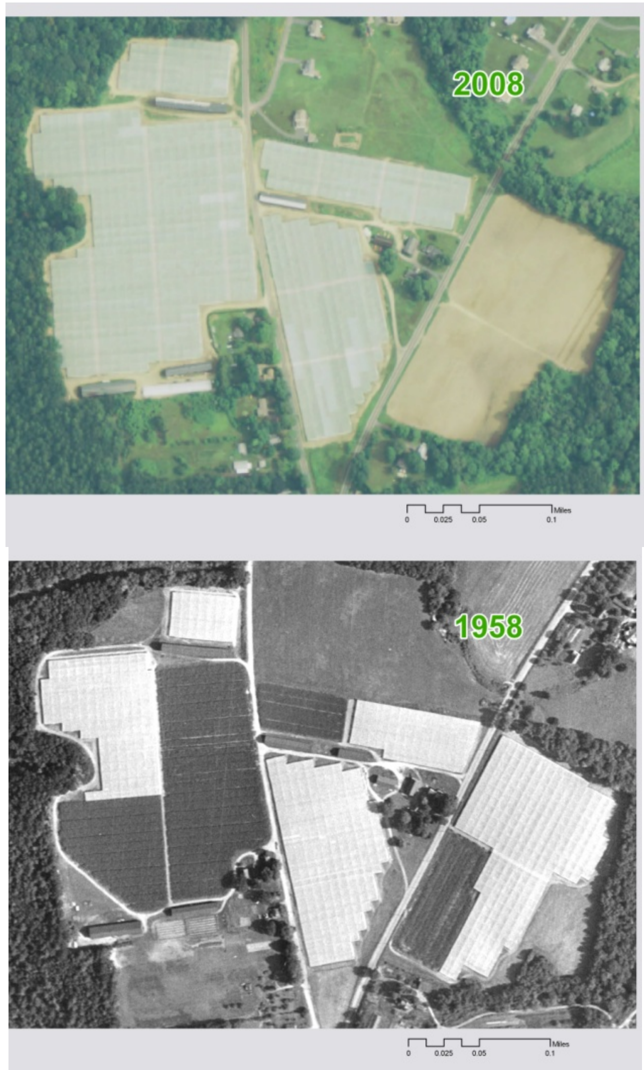


Figure 2. The distinctive shade netting for cigar wrapper tobacco makes it easy to identify on different types of photography.

Figure 3. The addition of farm records to the CLU shapefiles.
(Due to privacy regulations, the imagery cannot be displayed with the CLU files).

Studying Imagery with Vector Files and Tabular Data

Comparing imagery from one or several years with the CLU vector files is one of the most immediate interests of FSA, as relates to farm program management. With the addition of farm record files, as seen in Figure 3, it is possible to compare the fields on the ground with what has been reported as planted. It is possible to compare present fields with land use for the same area over the past 50 years, and at least get an approximate idea of changes. Another use of vector data was land planning data for a city. A shapefile of projected development from 2000 through 2025 was overlaid with CLU to determine the amount of agricultural land which would be lost to planned development in that city. This extends the temporal dimension into the future as well as the past.

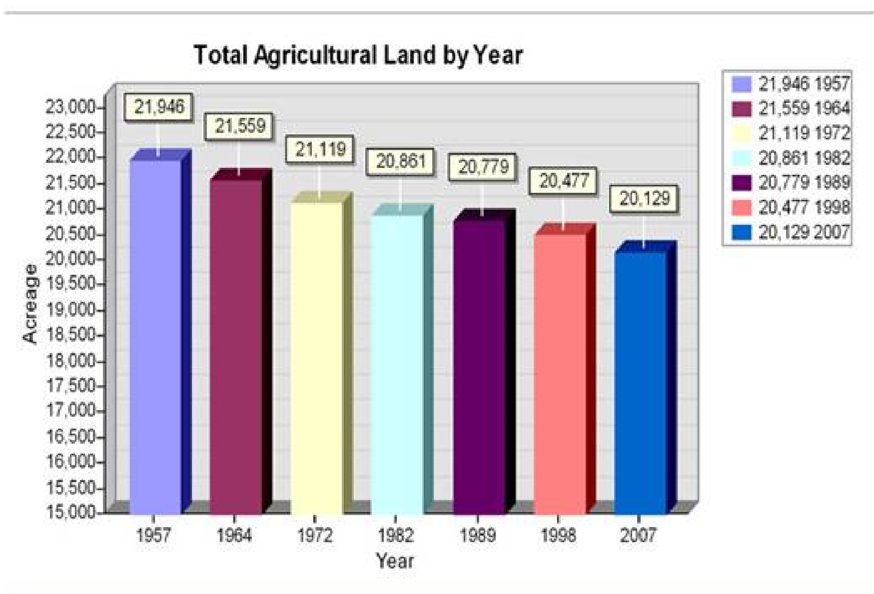


Figure 4. Vector files with land use classifications can be used to generate statistics and graphs about the imagery.

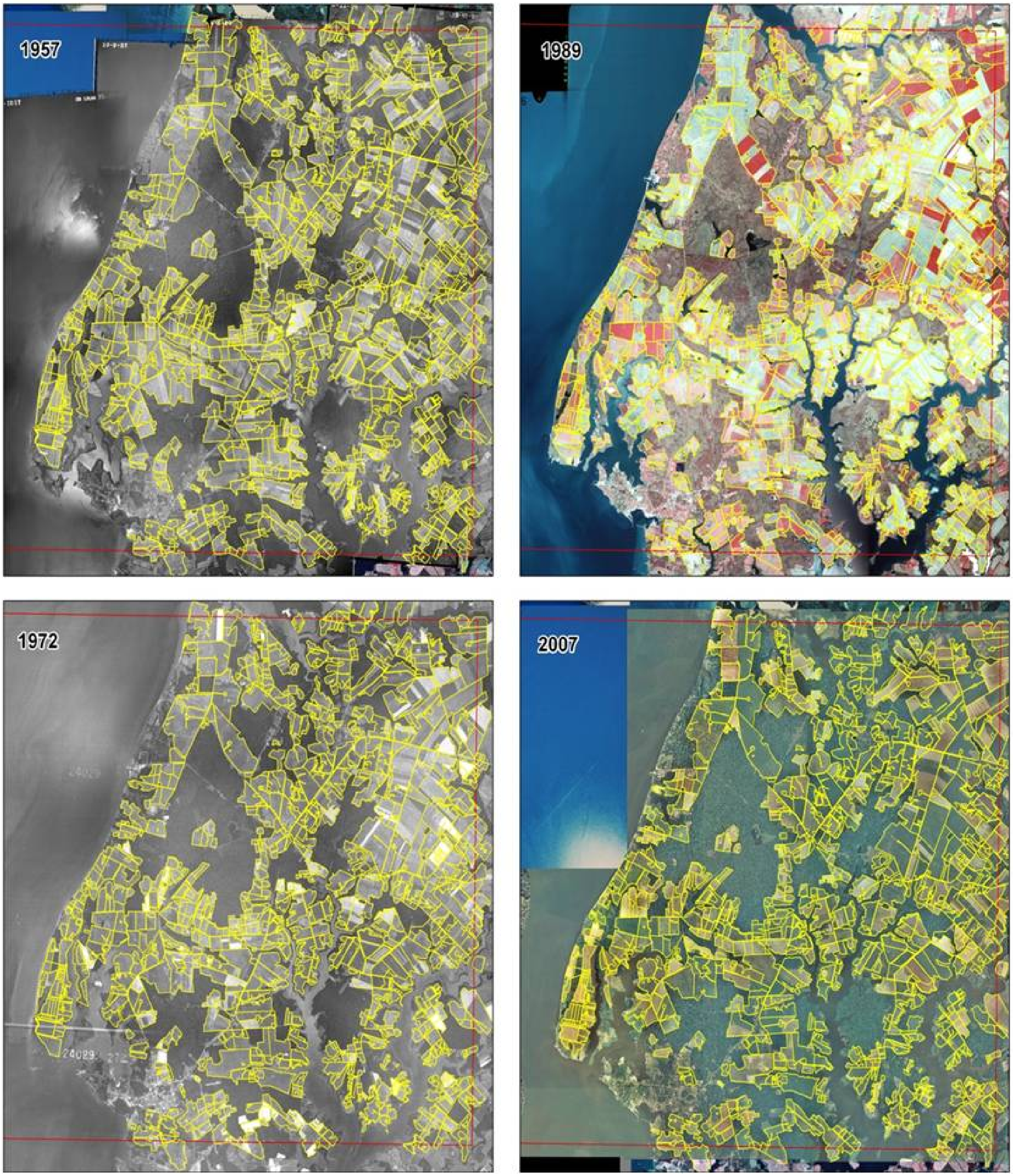
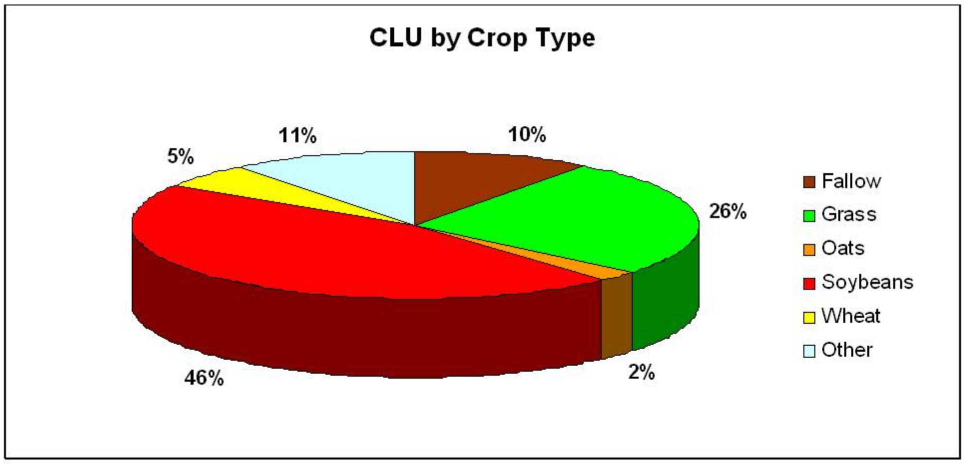


Figure 5. A time series study showing the loss of agricultural land. Agricultural polygons were hand digitized Accurate vector and tabular data can work together to greatly expand the value of the imagery. The imagery can also verify the accuracy of this ancillary data. Combining all available data is the next step needed for enhanced program management and more advanced analysis within FSA. Using all data sources, analysts can look for patterns of change, create statistics, and display results.



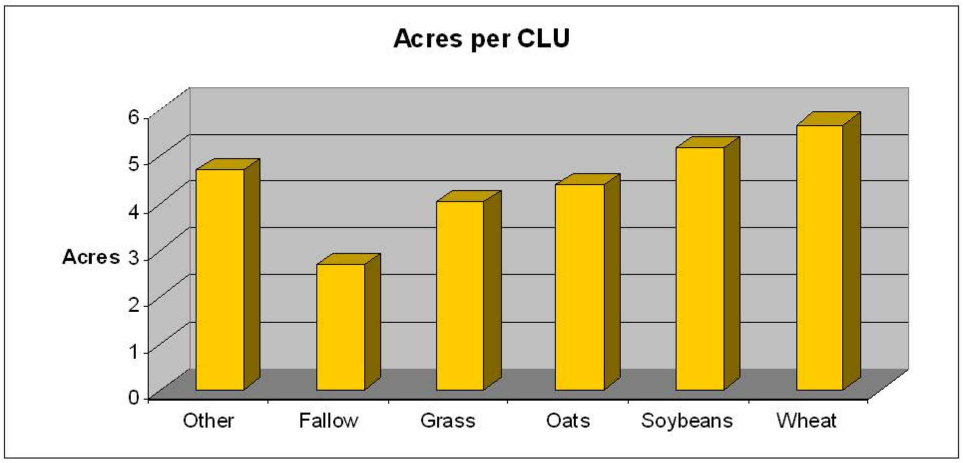


Figure 6. Statistics for a study displayed graphically.

CHALLENGES IN HISTORICAL ANALYSIS

One of the big obstacles to the use of vector data with historical imagery is locating or creating it. It would be relatively easy to georeference a historical map printed on paper or some other medium and digitize from it, but this would be tremendously time consuming. Some sort of automated procedures might be developed to extract vector files from this type of source.

Another obstacle in viewing vector data with imagery might be inaccuracy in it or in related tabular data. Since the tabular records have not as yet been spatially enabled, it is not easy for an FSA employee to reconcile the information in the records with what is really happening on the ground.

Another concern is with geometric accuracy; this is seen with the CLU files, which were hand digitized based on the MDOQs. The fear was that they would not match NAIP imagery, especially after the decision was made to orthorectify NAIP to true ground control points rather than the MDOQ imagery. Offset between linework and imagery, especially from historical film, would need to be resolved for analysis to be valid. The CLU files continue to improve as the NAIP program continually provides newer imagery, but matching them to older imagery might remain difficult.

Offset is also a problem in imagery – between different years of imagery, as well as within the historical mosaics. Any analysis – automated or manual- will be very difficult if the images do not match each other geometrically. A possible solution is creating DOQQs from the historical scans through orthorectification, which is being done at APFO in a very limited capacity. The rectification is done as a block in SocetSet, and the DOQQs cut from this.

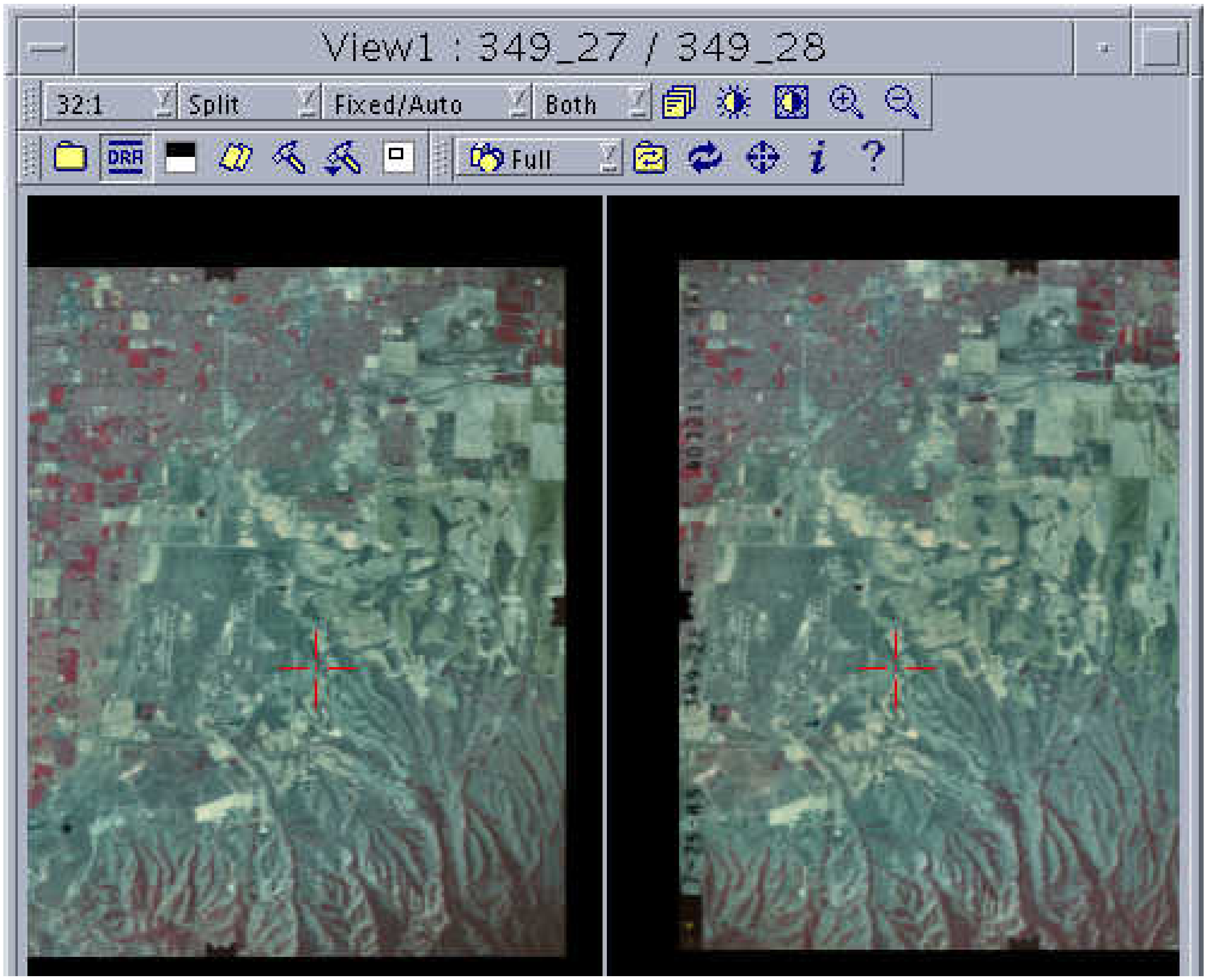


Figure 7. Selecting control points while creating DOQQs from historical imagery.
Orthorectification will output DOQQs which would be much more accurate than scanned exposures which have been georeferenced, using a process which is not a true photogrammetric solution. The biggest problems with creating orthos are locating usable control points and dealing with different flying dates within a mosaic.

USING OTHER IMAGERY SOURCES WITH NAIP

The studies did not investigate the use of other imagery sources with NAIP when planning a historical study, since the focus was on exploring ways in which the film-based resources in house could be used to benefit FSA users. Many state and local governments have imagery programs which could potentially be used along with the imagery USDA has acquired. The *Imagery for the Nation* Program, if implemented, would be a starting point for finding imagery on a national level, and NAIP would be one part of this. However, these sources would probably not contribute to the temporal aspect of imagery collection.

Multispectral imagery, now acquired in many NAIP projects, offers more options for automated processes, including supervised, unsupervised, and rule-based classification. Another source of multispectral imagery is Landsat, with free downloads of data from 1972. The advantages of satellite imagery over aerial photography are:

- It includes more bands of data, which provide more options for automated analysis techniques.
- The larger pixel sizes (30 meters as opposed to 1 meter in NAIP) require less storage space and processing time.
- There will be many more dates of imagery for a given scene than for NAIP.

Aerial imagery's advantages are :

- It offers more detail in the smaller pixel sizes.
- It generally has better tonal quality, especially in being free of cloud cover.

The newer four band imagery allows some of the same processing options as Landsat, and the option to resample the data to a more manageable GSD (such as 10 meters) could make processing time easier and classification easier to apply.

Figure 8. Comparison of NAIP and Landsat and from July 2008.

RESULTS OF THE STUDIES

Much of the agricultural land in the study areas around country have been converted to other land uses, such as residential, commercial, and recreational. The patterns of loss varied geographically in the chronology and rate of change. An interesting long term study might be to compare patterns of change in different locales and correlate them with other factors influencing the changes. These factors might include environmental factors, changes in agricultural technology, or increasing costs of land ownership, production, storage and transportation.

Any sort of temporal study would need to evaluate the purpose and data availability, as well as the size of the study area and amount of time available. Another concern is the level of detail to be focused on, and the difference between land cover and land use classifications. A study is easier – but less accurate- with fewer land cover categories. Land use categories need to be derived from land cover classifications, and require the subjective interpretations of the analyst.

SUMMATION

- Detecting change in agriculture over time is feasible with the necessary raw materials.
- Automated and manual techniques may both be used depending on scale, resolution, purpose of the study, and other factors. Many different methods can be used when setting up a change detection project.
- A thorough knowledge of imagery software programs and the behavior of digital imagery is necessary for successful use of automated classification procedures.
- Results will not be any better than the quality of the imagery and ancillary data, and the skill of the operator.
- Care must be taken with land cover as opposed to land use classifications. Automated procedures will identify land cover – the operator must select a classification system and translate land cover results into this system.
- The better the contextual data (vector or tabular data) one has, the more sophisticated and thorough the analysis can become.

Now we are beginning to understand:

- As we move through time, while current imagery helps us maintain current farm programs, historical imagery has untold value in arenas such as change analysis, trending over time, program administration, and much more we have not yet uncovered.
- Historical treasures should be preserved; temporal analysis cannot be done without data to back it up.
- Historical imagery is a snapshot in time, a history book that tells a story when analyzed .
- The value of historical data is augmented by the constant acquisition of newer imagery to detect change over time.
- The field seems wide open for additional study. FSA is only beginning to investigate the possible value inherent in adding a fourth dimension to geospatial analysis, through using its historical imagery products.

Appendix 1: Land Use Change Analysis done in southern Salt Lake Count, UT.